SCIENCE AND INDUSTRY

VOLUME VII

1902

SCRANTON, PA.
INTERNATIONAL TEXTBOOK COMPANY
1902

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SCIENCE AND INDUSTRY

Vol. VII January, 1902 No. 1

FRICTION—I

H. ROLFE

SOME NOTABLE INVESTIGATIONS INTO THE SUBJECT OF FRICTION—FRICTION ALWAYS ACCOMPANIES MOTION—NATURE AND CAUSE OF FRICTIONAL RESISTANCE—LAWS OF SOLID AND OF FLUID FRICTION—POINTS WHEREIN THEY DIFFER

A PROMINENT writer once prefaced his remarks on the laws of friction by saying that a good preliminary to their discussion would be to find out what they really were—a stricture that was not altogether unjustified. Of late years, however, considerable research has been carried on in this direction, and some of the laws as now generally accepted will be stated in the present article.

Much has been written on the subject of friction, and—in early times—much of it was inaccurate, also. The earliest work, in recent times, was done by the French engineer, Morin —about 70 years ago. His experiments, however, dealt only with light pressures and low speeds and, moreover, with dry surfaces; so that the knowledge thereby gained is not of much use in the majority of problems confronting the modern mechanical engineer.

Perhaps the most notable experiments, carried out under actual working conditions, were those conducted by Mr. George Westinghouse and Captain Douglas Galton in England in 1878, which experiments were the pioneers of their class. It was at this date that the Westinghouse Air Brake was being introduced into Europe. There was just then a great demand for continuous brakes in Great Britain, and the government, which—through the department known as the Board of Trade—exercises a control over all railways (as to their building, equipment, operation and, we believe, rates also), was desirous of seeing how matters really stood in this field, there being many brakes in use, all claiming the property of automatism and all the other possible virtues of a brake. The outcome was that Mr. Westinghouse offered his brake for the trial, and the Brighton Railway proffered the use of their road, rolling stock, and staff. Under the direction of Mr. Westinghouse himself, an experimental car (costing some thousands of dollars) was fitted up with dynamometer apparatus and an elaborate system of recording instruments. With this plant Mr. Westinghouse and Captain Galton conducted their now famous and oft-cited experiments and gave many new and important facts to the engineering world, their observations dealing with rail, wheel, and brakeshoe friction.

In 1883-4, the question of friction as relating to bearings (thus involving the closely-allied subject of lubrication) was examined into by Mr. Beau-

champ Tower for the British Institution of Mechanical Engineers. This was the first and most important investigation ever undertaken in this connection, and was a very valuable piece of work. Next may be mentioned the important work of Prof. Goodman, who, in addition to his experiments on journal friction, is also quite an authority on alloys, a very important and allied item in connection with the subject of bearings. The observation work of these two engineers has been supplemented by the valuable mathematical work of Prof. Osborne Reynolds. Much of interest in this direction has also been written in this country by Prof. Thurston, while in England a valuable book has recently been published by two railway experts, Messrs. Archbutt and Deeley.

We are all familiar—even if unconsciously—with the manifestations of friction; its all-pervading presence is evident to any one on giving the matter a little thought. When we reflect on the inconvenience that would result from having our floors and the bearing surfaces of our furniture, and in fact everything we handled, made as smooth as, say, virgin ice, the importance of friction is apparent. In fact, to employ an Irishism, the importance of friction is most brought home to us when this property is absent; the careful way in which we have to plant our footsteps on an icy road is a case in point. As a matter of fact, without this proof, the fact of our shoe-soles wearing out might tell us of the frictional resistance that was ordinarily present, for without friction, there would be no abrasion, and therefore no wear. This attribute of friction is everywhere present; the navvy with his pick or wheel-barrow, as also the golfer with his club, moistens his hands to get a "better grip"—really to increase the friction and give him a better hold. As the swordsman in the middle of an engagement could not conveniently do this, we secure the same advantage to him by covering his handle with sharkskin. What the mechanic would do without friction is hard to conceive; his keys, cotters, and taper-fit bolts would not hold; nuts would immediately slack back; no press fits could be got—however, it is unnecessary to enlarge hereon.

We call that cause "friction" which opposes the motion of one body over another; and we also know that the smoother we make an object, as judged by the eye (to mention touch would be arguing in a circle) the less frictional resistance does it oppose to motion over another body. However smooth it is made to appear, a microscopic examination will reveal a state of roughness—but with the inequalities becoming smaller and smaller as the smoothing process is proceeded with. Although, the further this operation of polishing is carried, the less friction there will be yet there arises an element of danger when the pressure exceeds a certain amount, for if the surfaces were quite clean, there would then be a more perfect exclusion of air or other medium, and hence a greater tendency for the two bodies to unite—especially if of the same material. Thus, in an actual bearing, if the lubricant gave out, and the surfaces were swept clean, the smoothness and truth of these surfaces would be an exciting element in their tendency to cohere together or seize. While familiar, then, with the effects of friction, people are not as yet decided as to the real cause of this property, or attribute, of all matter. To say that a body is rough is of course no answer, in the scientific or engineering sense. Some inquirers have formulated a theory that the surface of

a body is ridged or notched as in Fig. 1 —exaggerated. Now, any one familiar with the processes of working in metal will readily grant the existence of something of this kind. A surface that has been tooled over will be a series of decidedly pronounced regular ridges, diminishing as a broader tool and a finer feed are employed. If one such body A slides over another B, Fig. 2, so that the line of cut on A is parallel to that of B, and at right angles to the direction of motion, then the resistance experienced will be comparatively great, owing to the ridges engaging each other.

When A is moved relatively to B, there is impact between the surfaces of each adjacent pair of ridges, and to maintain the motion, there must either be an abrasion and leveling down of these ridges or else A must "ride over" B, which it will do in a series of small and scarcely perceptible lifts. The actual resistance experienced will depend on the depth and steepness of the ridges (i. e., the *roughness* of the surface). If the sides of the ridge are not steep, the width of base being wide relative to the depth, the lift is not only small, but the principle of the inclined plane comes into play, and the motion is an easier one. If A is set so that its ridges are at right angles to those of B, the resistance will be less, because then A will simply ride along on B without any rising and falling; there will be a resistance, though, owing to the fact that the bearing surface consists of narrow sharp edges, which will, granted sufficient pressure, cut into and abrade the surface B, thereby increasing the actual unit surface friction. If, however, the lines of cut are not only parallel to each other but also to the line of motion, there will be even less friction than in the last case, particularly if the ridges exactly match each other.

In each of the above cases, however, there will be a resistance due to the fact that the tool, in cutting, really *breaks off* the chip and thus leaves a roughened surface. The reader is aware how a piece of iron opens up at the surface when a heavy cut is taken, the roughness being very evident when the hand is drawn along the piece; the operation that we call "cutting" really consists for the most part of tearing and breaking, the ensuing roughness being most noticeable in the case of steel that has been machined dry. It seems entirely feasible that this roughness is also present, only in less degree, however fine the cut is. By rubbing down the surfaces on a grindstone or buffing wheel, the above-mentioned ridges will be replaced by smaller ones; each small one, however, will still be an obstacle in the path of some other ridge on the adjacent piece, and this antagonism creates the resistance to motion that is known as frictional resistance. The effect will be still further diminished by employing the scraper, a skilful use of which, in conjunction with a surface plate, will bring the two surfaces more nearly into the condition of true planes, in which, of course, there are no prominences at all. The object then in view, when seeking two surfaces that shall work on each other with a minimum of friction, is to remove all high places and get what we know as a plane, level, or smooth surface. It is merely an incidental that, as we proceed with this process, the light striking the surface is less broken up,

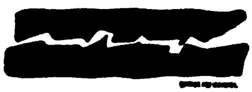


FIG. 1

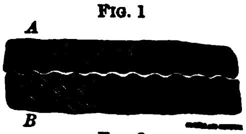


FIG. 2

and being thus more completely reflected, the body appears bright and polished. It is not really the polish *per se* that induces the minimum of friction, but the state of the surface that causes this appearance to be presented.

As regards the frictional resistance of apparently smooth metallic surfaces, some writers have tried to explain it on the ground that metals have a surface like the nap on a felt hat. Certainly, observation seems to endorse this view, it having been noted that journals which have run in one direction for a length of time satisfactorily, get hot when run the other way, and then after a time run as cool as before—when presumably the nap, or grain, has become fairly set in the new direction. The presence of this nap in the first place may be due to the breaking up of the surface—the forcible *tearing* apart of the fibers—when machining. It is at least a coincidence that fibrous materials like wrought iron and timber evince more friction than crystalline ones such as cast iron, bronze, and babbitt.

The engineer has at different times to invoke the aid of friction and at others to overcome it. In the first case he is concerned with the action of dry surfaces, or "solid" friction; he is then desirous of arresting motion, as in brake gears, friction clutches, etc. He has to deal with the friction of lubricated surfaces, or "fluid" friction when desirous of facilitating motion, as in bearings of all kinds, such as journals, guides, glands, etc.

The laws or principles that present themselves in connection with the two kinds of friction differ considerably in some respects. To deal with solid friction first: (1) The frictional resistance is practically proportional to the normal pressure between the two surfaces. (By "normal" is meant that the pressure is perpendicular, or square, to the surfaces; if otherwise applied, a portion of the thrust would be taken up in producing or tending to produce sliding.) (2) This resistance is, for low pressures, practically independent of the speed. (3) It depends largely on the nature of the materials in contact. (4) It is slightly greater for a state of rest than of motion. (5) It is greatest when just starting from rest, and decreases as the duration of contact elapses. This was particularly noted in the brake trials referred to; probably due to the polishing up of the surfaces, to a gradual cleansing of the contaminated surfaces, and to the particles abraded from the cast-iron brakeshoes filling up the interstices and so floating the one body over the other, exactly as graphite is intended to do nowadays when applied as a lubricant. (6) It is not greatly affected by temperature. (7) Abrading and seizing occur when the pressure becomes excessive. (8) The frictional resistance is always greater immediately after reversing the direction of the sliding motion.

The corresponding results for fluid friction are as follows: (1) When the bearing is oil-borne, the resistance is practically independent of the pressure. (This applies to bath lubrication and, in less degree, to pad and siphon lubrication also.) (2) The resistance varies directly as the speed, for low pressures. At high pressures, however, the friction is great at low velocities, thence decreases until about 100 feet per minute is reached, and thereafter increases again—about as the square root of the speed. (In connection herewith it should be remarked that actual fluid friction varies as the square of the speed; therefore, as the

friction of a thoroughly-lubricated surface is observed to vary as above mentioned, there must be involved something more than the friction of the lubricant in itself.) (3) If the bearing is flooded (the journal being oil-borne) the resistance is to a very great extent independent of the nature of the material forming the rubbing surfaces. If the lubrication falls off, however, and the surfaces come into contact, the nature of the metals asserts itself, the condition of dry or solid friction then resulting. (4) Friction when the body is in motion is very much less than when just starting, because during the preceding state of rest, the lubricant—especially if possessing but little oiliness—will have been more or less thoroughly squeezed out, thus bringing about more nearly a metallic contact. (5) If two well-oiled surfaces are brought together and then set in relative motion, the friction increases as time progresses; because the lubricating film squeezes down under pressure. Also, the effect that brings about the reduction in the case of dry friction is not here present, because the surfaces not being in contact, there is no cause at work to alter their nature. (6) The resistance varies with the changing of the temperature,

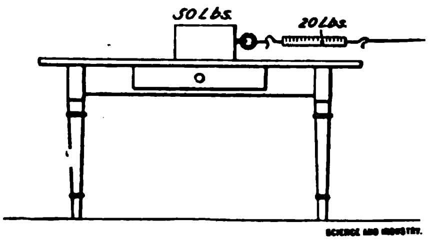


FIG. 3

owing to the effect on the viscosity or body of the oil, and also to the expansion of the parts, giving in some cases a tighter fit and hence grip of one surface on the other. (7) The same law obtains in this case as in solid friction; only the limit is very much higher. Thus, in one experiment a bearing that seized at 80 pounds per square inch when dry, ran when lubricated,

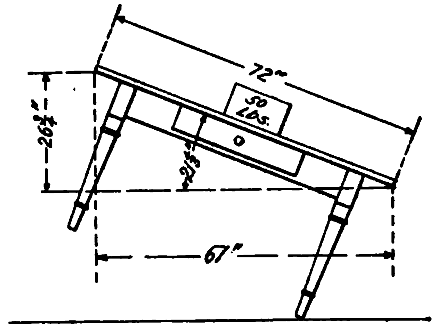


FIG. 4

with 600 pounds per square inch before failing. The limit of pressure depends on the viscosity or rather the oiliness of the lubricant. (8) The same effect is observed as in dry friction. It is thought that the metal —however highly polished to the eye—has a grain in one direction, and that when running against the grain (like rubbing the nap on a hat the wrong way) the friction is necessarily higher. After a few hours of the new direction, the friction gets back to the original amount—having in that interval presumably set the nap the other way.

The term "coefficient of friction" is an ever-recurring one in connection with any discussion of the present subject. If we place a block of wood weighing 50 pounds on a wooden table and attach a spring balance to it, and exert a steady pull on the same, it will register, say, 20 pounds (Fig. 3). Then the ratio of the pull to the dead weight is $\frac{20}{50}$ or .4. Also, if we tilt the table up steadily, the block will, after a certain elevation is reached, move down it (Fig. 4). The angle of tilt will be

found to be 21¾ degrees, or by measurement, if the table is 6 feet long, one end will be found to be 26¾ inches higher than the other, and their horizontal distance apart about 67 inches.

$$\frac{26\frac{3}{4}}{67} = .4, \text{ nearly.}$$

This ratio, which by the way, is a measure of the angle—the function known as the tangent, in fact—is the same as found above. The angle in question is called the angle of repose for the particular materials employed; it is also spoken of as the "friction angle." If we were to substitute metallic surfaces, smooth and oiled, the ratio of the pull to the dead weight, would be about .1. The angle of repose will be found to be about 6 degrees and the

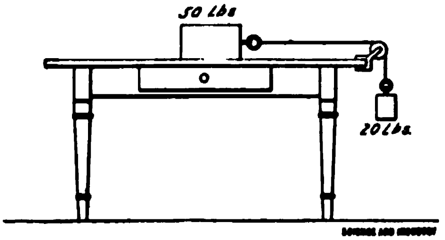


FIG. 5

tangent of this angle is $\frac{1}{10}$. If we were to hang a weight over a pulley, as in Fig. 5, the weight required to move the block would be 20 pounds, ignoring the friction of the pulley axle itself.

Another point we should notice, and one that endorses Law 4, is that after the weight is once started, the weight recorded on the spring balance would—if the same rate of motion were maintained—drop below the 20-pound mark, and this, too, independent of any inertia effects. Similarly if, while the weight was falling, we could arrange to continually take off minute amounts every instant, the velocity would be maintained constant; if we kept the same weight on, the velocity would be continuously accelerated. Here again, we would remark, this result would ensue, over and above the acceleration due to gravity.

In regard to fluid friction, it may occur to the reader that the friction of a body in water is less than in oil, and such is actually the case. The ordinary textbook experiment is to suspend a hollow cylinder inside a vessel filled with water; if the supporting wire be twisted through a certain angle and then released, the cylinder will swing around until the twist is unwound and the wire twisted up a certain amount in the other direction. It will thus vibrate, twisting and untwisting, until it comes to rest. Obviously the greater the friction all around the sides of the cylinder, the sooner will the latter come to rest. If, then, for the water we substituted oil or, worse still, molasses or tar, the sooner should we expect the motion to cease; and this in fact is borne out by experiment. Since then, water opposes less frictional resistance to the motion of bodies in contact with it, why not employ it in bearings? The answer which is readily deduced is that water has practically no power of maintaining a film under pressure; it would quickly squeeze out and allow the surfaces to come into contact. Thus the desiderata in a lubricant are: an ability to maintain a film under high pressure and temperature, and at the same time cause but little internal friction and, we may add, also possess good heat-conducting qualities.

In the next issue we shall say something about frictional work and heating; about loss of efficiency in machines; and about the general statement—an untrue one—that friction always decreases with the rubbing speed.

(To be Concluded.)

BOILER HORSEPOWER

WILLIAM BURLINGHAM

BEFORE entering upon the subject of the capacity of steam boilers, it is well to consider a few points relative to steam making, efficiency, and the requirements of a perfect boiler.

The prime requisite of a boiler is to furnish a quantity of energy in the form of measurable heat and molecular activity. The technical term for this combination is "latent heat."

Suppose that we should take a pound of ice at the temperature of absolute zero, equivalent to 460° below the zero of Fahrenheit. Now add heat to this ice until it has reached a temperature of 492° absolute or 32° F. From this point the addition of heat makes no sensible change in the temperature of the ice, until enough heat has been added to have made the ice 283° hotter, if this were possible. As it is not possible, the heat is absorbed by the ice in such a manner that, although melted, the temperature of the resultant water remains at 32° F.

The moment that 283° of heat have been added, the water commences to increase in sensible heat for every degree above that, until it has reached a temperature of 672° absolute, or or 212° F.

We have now reached another critical point and can add heat to the water without increasing its measurable temperature until enough heat has been added to have raised the thermometer 966° or to 1,178° F. All the water has now become steam, although still at the sensible heat of 212° F.

About four-fifths of the heat added to the pound of ice has now disappeared and is not sensible to any of our instruments for measuring heat.

From this point if heat be added it increases the temperature in a ratio proportional to the pressure and volume.

It is not known if there is any other critical point, until the component parts of the steam are separated into their original gases; that is, oxygen and hydrogen.

The heat, which is stored in the water and steam, and which is insensible to our thermometer, is called "latent heat," and on this heat depends the ability of the steam to do work.

Our position at present, then, is this: A given quantity of water at a given temperature has been converted into steam at a given temperature by having a certain amount of heat applied to it, and that heat is now ready to appear, by a reverse of the process, in the form of power at the steam engine.

It is impossible to utilize all the heat given out by the coal for the reason that a portion of the products of combustion escape through the chimney or smoke pipes, the temperature of the hot gases at that point ranging from 600° to 1,000° F.; although the last named figure usually indicates a poorly designed uptake and stack. Another portion of the gases is lost in radiation from the outside of the boiler before reaching the water, and from the pipes after the steam has left the boiler.

The portion which penetrates the metal heating surface of the boiler, and which is absorbed by the contiguous water, is the only part of the heat that is useful to us. The loss of heat at the chimney will generally run from 20 to 40 per cent.

One pound of pure carbon when burned will yield an average of 14,500

heat units, each equal to 778 ft. lbs. of work. If all this heat could be utilized in one hour it would exert about 5.697 horsepower. As it is, under present conditions of utilization of the heat from coal, we can only realize in one hour from one-quarter to one-half of a horsepower. The number of heat units equivalent to this would evaporate about 15 lb. of water from 212° F. at atmospheric pressure.

A good marine or land boiler of today will evaporate about 9 lb., therefore but about 60 per cent. of the heat is used.

The rule for finding the efficiency of a boiler is as follows (see "Foley's Mechanical Engineers' Reference Book"):

"Given the heat value of the fuel in thermal units per pound, and the number of pounds of water actually evaporated per pound of fuel burned; also the temperature of the feedwater; to find the efficiency of performance the initial steam pressure being known."

HEATING VALUE OF AMERICAN COAL,
BABCOCK & WILCOX

Kind	Heating value per pound combustible	Theoretical evaporation pounds water from and at 212° F. per pound of combustible
Anthracite	14,900	15.42
Semi-anthracite	15,500	16.05
Semi-bituminous:		
Best	15,800	16.36
Poorest	15,700	16.25
Bituminous:		
Best	15,300	15.84
Poorest	14,200	14.70
Lignite:		
Best	12,900	13.35
Poorest	11,000	11.39
Wood:		
Kiln dried	7,245	7.5
Air dried	5,600	5.8
20% water		

NOTE.—Per pound combustible means combustible portion of coal.

By equivalent evaporation of pounds of water from and at 212° per pound of combustible is meant that the evaporation of water is considered to have taken place at mean atmospheric pressure, and at the temperature due to that pressure, the feedwater also being assumed to have been supplied at the same temperature; this is equivalent to 965.7 B. T. U. per pound of water.

An example of the use of the above formula follows:

Find the efficiency of a boiler which evaporates one pound of water per pound of coal at 85 lb. pressure (100 lb. absolute). The feed supplied at 120° F. and fuel average American bituminous coal.

Total heat from 0° F. at 100 lb. absolute	1213.8
Temperature of feed	120.
Supplied for each pound of steam	1093.8

See "Steam Table" in textbooks under heading "Total Heat From Ordinary Zero F. British Units."

Therefore, $1093.8 \times 9 = 9844.2$ units used out of the 14,750 in each pound of coal. Then to get the efficiency divide 9844.2 by 14,750, which gives .667.

Our boiler has 66.7 per cent. efficiency, which is pretty near the limit for a good boiler. The requirements of a perfect boiler, partly from Mr. Babcock's lectures, are as follows:

First.—Best material, simple in construction, perfect in workmanship and durable in use.

Second.—Steam and water capacity sufficient to prevent any fluctuation in pressure or water level.

Third.—A large water surface for the disengagement of the steam from the water to prevent foaming.

Fourth.—Sufficient steam room.

Fifth.—A constant and thorough circulation of water throughout the boiler.

Sixth.—A great excess of strength over any legitimate strain.

Seventh.—Combustion chamber so arranged that the combustion of the gases commenced in the furnace is completed in the chamber before escaping to the chimney.

Eighth.—The heating surface as nearly as possible at right angles to the currents of heated gases, so as to break up these currents and extract the entire available heat therefrom.

Ninth.—All parts readily accessible for cleaning and repairs.

Tenth.—Proportional for the work to be done and capable of working to its full rated capacity with the highest economy.

Eleventh.—All fittings of the very best.

The preceding requirements are of course general in their nature, and many minor points are of nearly as much importance, but to thoroughly treat of them would necessitate a separate article on boiler design.

There is actually no such thing as the horsepower of a boiler, for the term "horsepower" is applicable only to dynamic energy, while the power of a boiler is static energy.

However, as the boiler furnishes energy to the steam engine, it is convenient to designate its capacity by the actual measured effect on the steam engine; in other words, we use the engine as a measuring rod for the boiler.

It will be easily seen that an immense variation can take place in the rated capacity of a given boiler; the varying effect being produced by a difference in quality of coal, the skill of the fireman, the amount of horsepower developed per pound of coal burned on the grate, and the amount of draft.

The preceding causes will evidently effect the same boiler to vary its power.

Now add to this the different types of heating surface arrangements, water circulation, flues, uptakes, and stack designs, and one begins to have an idea of the difficulty of estimating the horsepower of a boiler by looking at the outside of it, as is quite possible in the case of an engine.

A boiler really has no horsepower until it is connected up and furnishing power to a prime mover, and it is then necessary to know the type of engine, kind of coal used, and various other particulars before one can give an estimate, and it cannot be done then unless one has had previous experience with that type of boiler.

The standard of horsepower adopted by the Committee of Judges, at the Centennial Exposition, has been accepted by all prominent steam users and is endorsed by the American Society of Mechanical Engineers. It is as follows:

"An evaporation of 30 lb. of water per hour from a feedwater temperature of 100° F. into steam at 70 lb. gauge pressure, which shall be considered to be equal to 34½ lb. of water evaporated from a feedwater temperature of 212° F. into steam at the same temperature."

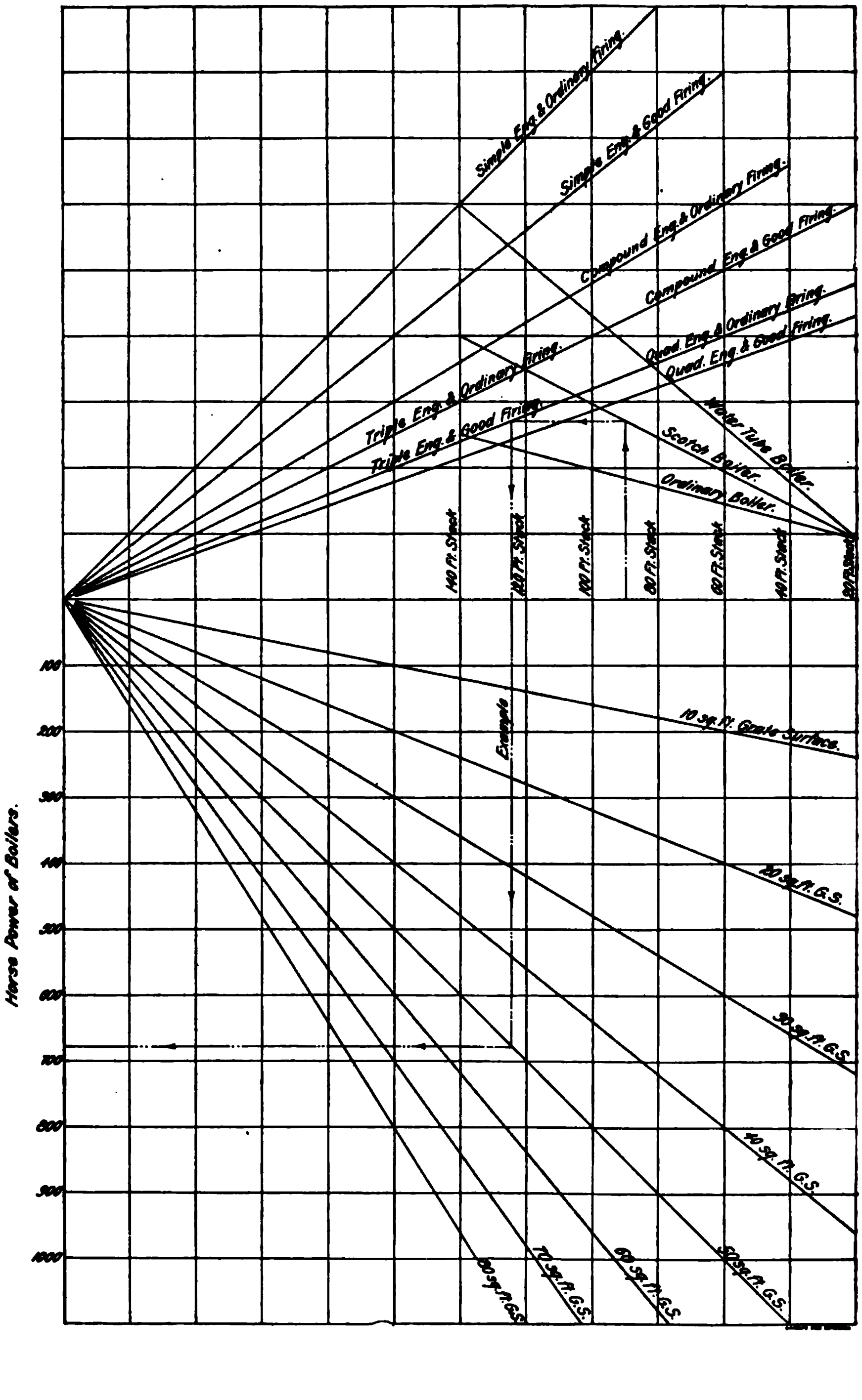
This for good engines, according to Prof. Thurston, would be about 25 lb. of water working with 64 lb. of steam, and for the best engines 15 lb. of water per 100 lb. steam pressure per hourly horsepower.

This formula is not convenient for reducing to the familiar term of "horsepower," while standing on the stoop of the boiler shop guessing at the power of the boiler.

The purpose of this article, and the accompanying chart, is to furnish an empirical method of finding the horsepower of a boiler.

Roughly, it is true, including in the estimate four principal factors, viz.: kind of firing, amount of draft, type of boiler, and prime mover.

Boilers of heating and distillery


Simple Eng. & Ordinary Firing.
Simple Eng. & Good Firing.
Compound Eng. & Ordinary Firing.
Compound Eng. & Good Firing.
Quad. Eng. & Ordinary Firing.
Quad. Eng. & Good Firing.
Triple Eng. & Ordinary Firing.
Triple Eng. & Good Firing.
Water Tube Boiler.
Scotch Boiler.
Ordinary Boiler.
140 Ft. Stack
120 Ft. Stack
100 Ft. Stack
80 Ft. Stack
60 Ft. Stack
40 Ft. Stack
20 Ft. Stack
Example
10 Sq. Ft. Grate Surface.
20 Sq. Ft. G.S.
30 Sq. Ft. G.S.
40 Sq. Ft. G.S.
50 Sq. Ft. G.S.
60 Sq. Ft. G.S.
70 Sq. Ft. G.S.
80 Sq. Ft. G.S.
Horse Power of Boilers.
100
200
300
400
500
600
700
800
900
1000

plants, etc., are not taken into consideration. It is only intended for those boilers in which the steam is used by that type of prime mover wherein the horsepower can be indicated. The table is intended for average work and any special boiler must be calculated for its own work.

For instance, a boiler may use oil or a mixture of slack that hardly deserves the name of coal.

The conditions for which this table is intended are as follows:

Fuel, average quality of bituminous coal as may be found throughout the country; firing, such as would obtain in the ordinary machine shop, or good firing, such as in large electric light plants.

The coal per horsepower of the engine is averaged from a large number of engine trials.

It must be understood that the results obtained in horsepower are only for general use and are not supposed to be as accurate as would be obtained by an exhaustive test.

The curves may be altered to suit any particular class of boiler or engine.

The same principle may be used to work out a series of horsepower curves, using the heating surface and evaporation of water per pound of coal in accordance with the standard method of determining horsepower.

An example of the method of working the curves is shown by the dotted lines.

We have a Scotch boiler 50 sq. ft. grate surface, 90-ft. stack, with good firing to furnish power to a triple expansion engine. What is the probable horsepower of the boiler?

Method of procedure:

Follow a line from 90-ft. stack until it cuts oblique line marked "Scotch Boiler"; thence across to line marked "triple engine and good firing," and thence to 50 sq. ft. G. S. A line carried from this latter intersection to the edge will give the horsepower.

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500 K. W. GENERATORS DRIVEN BY GAS ENGINES

THE Sprague Electric Company has recently closed an interesting order for three-Lundell split-pole 500 K. W. engine type generators, with speed of 100 R. P. M., and wound for 250 volts, to be direct connected to gas engines.

These three generators of 500 K. W. capacity each will be installed in the new works of the Lackawanna Iron & Steel Co., of Buffalo, and are designed for a continuous overload of 25 per cent. at a high efficiency.

The gas engines will utilize as fuel waste gas from the coke ovens of the Lackawanna Company.

These will probably be much the largest generators in this country ever operated by direct-connected gas engines, and the method of utilizing waste gases for such large amounts of power has never before been attempted in the United States.

The Sprague Electric Company has been very successful with the split-pole machines, as their ingenious design, high efficiency, and remarkable endurance, give them the best possible commercial value.—Exchange.

SIMPLE LESSONS IN ALTERNATING CURRENTS—VIII

Some Peculiarities Due to Self-Induction and Capacity

HAVING studied the graphical method of representing alternating currents, we are now in a position to look into some of the peculiarities they exhibit as compared with direct currents. After this has been done, the laws governing the flow of alternating currents will next be taken up together with examples of simple problems that illustrate the application of these laws. If alternating and direct currents, along with a few commercial measuring instruments, are available, it is an easy matter to perform experiments to illustrate the effects mentioned in the following.

Most of the peculiarities that alternating currents exhibit, as compared with direct currents, are due more or less indirectly to the fact that an alternating current is constantly changing, whereas a continuous current flows uniformly in one direction. Whenever a current flows through a wire, it sets up a magnetic field around the wire, and since the current changes continually, this magnetic field will also change. Whenever the magnetic field surrounding a wire is made to change, an E. M. F. is set up in the wire, and this *induced E. M. F.* opposes the current. For example, suppose we take a bundle of iron wires and wind on them, say a few hundred turns of insulated wire having a resistance of 5 ohms. If we connect this coil across a 100-volt direct current circuit, a current of 20 amperes will flow, because from Ohm's Law we know that current $= \frac{\text{E. M. F.}}{\text{Resistance}}$, hence, in this case, the current would be $\frac{100}{5} = 20$ amperes.

Suppose, now, that we connect the same coil to a source of alternating current giving the same voltage (100 volts effective) at, say, a frequency of 60 cycles per second. We will find that the ammeter will not register 20 amperes as before, but considerably less than 20 amperes. The resistance of the coil in ohms, or the *ohmic resistance* as it is sometimes called, has not been changed in any way, and the voltage applied is the same as before, but the current is less because the alternating current sets up a varying magnetism through the iron core, and the varying magnetism threading through the coil in turn sets up an induced E. M. F. that chokes back the current. The coil is said to have *self-induction* because it is capable of setting up lines of force through itself and giving rise to an induced E. M. F. Many devices met with in alternating-current work have self-induction. A long transmission line has a certain amount of it, as have also induction motors and transformers. Incandescent lamps have very little self-induction, because the single loop, which constitutes the filament of the lamp, is able to set up but a very small amount of magnetism around itself. A water rheostat has very little self-induction, and resistances of this kind are usually spoken of as *non-inductive resistances.*

Coming back to the coil mentioned above, we note that a device which possesses self-induction tends to choke back, as it were, the flow of an alternating current. Direct current would flow through the resistance of 5 ohms the same as any other resistance, but the fact that self-induction is present makes a great difference in the amount of alternating current that the given

alternating E. M. F. of 100 volts can force through the coil.

Another peculiarity of alternating currents, or rather, in this case, of alternating E. M. F.'s in connection with an inductive circuit, is brought out by the arrangement shown in Fig. 1. *L* is an incandescent lamp connected

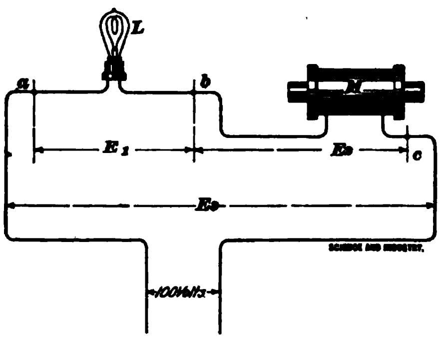

FIG. 1

in series with a coil *M*, which has a considerable amount of self-induction. The two are connected across a 100-volt alternating-current circuit. Now, if these two devices had been connected across a direct-current circuit, and if the voltage E_1 between points *a b* were measured by means of a voltmeter and added to the voltage E_2 obtained between *b c*, the sum of the two would, of course, be equal to 100 volts. If, however, we measure these two pressures when alternating current is flowing and add the results, we get the apparently impossible result that the arithmetical sum is greater than the line voltage E_3.

Fig. 2 shows another condition where alternating currents exhibit a peculiarity. If we take a number of sheets of tin foil and interleave them with a corresponding number of slightly larger sheets of waxed paper and then press the whole mass tightly together, we will have an electrical *condenser*. Alternate sheets are connected together to form one terminal, and the intervening sheets form the other terminal. In Fig. 2 the sheets of tin foil are represented by the lines, but the sheets of paper have been omited in order not to confuse the figure. *T* and *T'* are the two terminals of the condenser. Note particularly that there is no electrical connection between *T* and *T'*; if a direct current were applied to the terminals, no current could flow unless the insulation between the sheets broke down. If a galvanometer *G* were connected in circuit and a direct E. M. F. applied, it would be noticed that just after the pressure was applied a current would flow for a short interval; also, that if the terminals *a b* were disconnected from the source of direct current and connected together, the galvanometer would give a deflection in the reverse direction. There is a momentary current just at the instant the condenser is *charged*, and a reverse momentary current when it is *discharged*. This action will be understood by referring to Fig. 3. Here *A* represents a cylinder in which a piston *p* may be moved. *R* is a reservoir

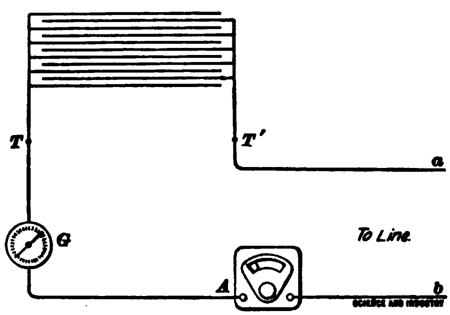

FIG. 2

connected to *A* by means of a pipe *l*. Suppose that *p* is in the extreme left position, as shown, and let it be forced in to the dotted position *p'*, and held there. During the time that *p* is moved from left to right a current of air flows through the pipe *l*, and the air in the reservoir *R* is compressed. If the

pressure on p is removed, the piston moves back to its former position and a current of air flows back through the pipe l. The reservoir R corresponds to the condenser. When the condenser is charged, a certain quantity of electricity is forced into it under the applied pressure, and when this pressure is removed and the terminals of the condenser connected, the charge flows back as the condenser becomes discharged. With the exception, therefore, of the momentary charging current, a direct E. M. F. applied to a condenser can force no current through it, and the circuit behaves as if there were a break in it, which there actually is, because there is no electrical connection between the plates of the condenser.

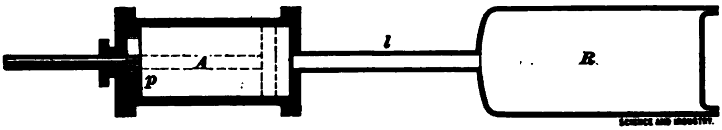

FIG. 3

If the condenser, Fig. 2, is connected to a source of alternating E. M. F. and an ammeter A connected in circuit, it will be found that the ammeter will indicate a current. The circuit acts just as if it were complete, and we have the peculiar effect of a current apparently flowing through a circuit which has a complete break in it. What actually occurs is, that when the current flows in one direction the condenser is charged, and when the current reverses the condenser discharges. The effect is much the same as if the piston p, Fig. 3, were moved back and forth, thus causing an alternating current of air to flow back and forth in pipe l. The ability of a device of this kind to take up a charge of electricity is known as its *electrostatic capacity*, or simply its capacity. For example two long parallel wires, as a transmission line, have a certain amount of capacity, and if two lines of this kind are connected to an alternator, the ammeter will indicate a current, even though the lines be perfectly insulated and have no connection whatever with each other. The amount of charge that a condenser can take up depends upon the capacity of the condenser and the pressure applied to it. The capacity is measured in *farads*, and a condenser has a capacity of 1 farad if an applied pressure of 1 volt is able to force a quantity of electricity into it, which is equal to the quantity represented by 1 ampere flowing for 1 second (i. e., 1 coulomb). A farad would be an exceedingly large capacity, much larger than the capacities met with in practice, so that the practical unit of capacity is the *microfarad*, or one one-millionth of the farad.

In alternating-current work, capacity is usually met with in connection with long, overhead lines or underground cables. Ordinary electrical devices, such as lamps, motors, etc., have little electrostatic capacity.

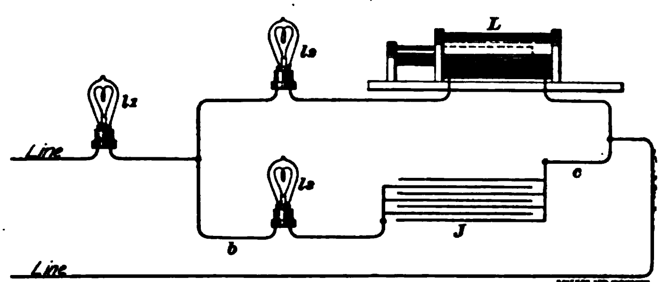

FIG 4

Capacity, like self-induction, can produce some very peculiar effects in

an alternating-current circuit aside from the peculiarity already referred to, namely, that of a current apparently flowing through a circuit with a break in it. Fig. 4 shows an arrangement that strikingly illustrates a peculiar effect of self-induction and capacity combined. l_1 is an incandescent lamp, and l_2 and l_3 are also lamps of the same kind as l_1. L is an adjustable self-induction made up of a coil that can be slid over an iron core. J is a condenser. L and J are each in series with a lamp, and are each in one of the branch circuits into which the main circuit is split. If this combination were connected to a direct-current circuit, no current at all would flow through branch $b\,c$ on account of the condenser. If, however, alternating current is applied, current will flow through each branch. The striking point is, that if L be adjusted to the proper amount the peculiar result is obtained that lamp l_1 can be made to burn at a dull red while lamps l_2 and l_3 burn up to full brightness. In other words, the sum of the two currents through l_2 and l_3 is less than either current singly, and the current flowing in the main circuit is less than either of the currents in the branch circuits. Such a result would, of course, be impossible with direct currents.

The above experiments illustrate a few cases where alternating currents differ in their behavior from direct currents. These effects are due to the fact that the current is continually changing and that either self-induction or capacity is present in the circuit. Either of these tend to displace the current and E. M. F. in their phase relation, and a study of the way in which they do this and the effect that they have on the flow of the current will place us in a position to solve many of the problems that ordinarily come up in connection with alternating-current work.

SETTING THE CUT-OFF ON AN AUTOMATIC ENGINE

W. H. WAKEMAN

IRREGULAR SPEED AND LOSS OF STEAM CAUSED BY UNEQUAL CUT-OFF—ADJUSTING THE CUT-OFF BY THE INDICATOR AND WITHOUT IT

IF engineers and steam users who have not given the matter particular attention should make an investigation, they would probably be surprised to find that scores of automatic engines are operated at a great disadvantage, simply because the point of cut-off is longer on one stroke than it is on the other, the results of which are irregular speed, unsteady belts, and waste of fuel.

Cases are sometimes found where unequal cut-offs are desirable, but they form exceptions to the general rule, and are required because defects have developed which must be taken into consideration. As illustrating this point I will mention a case where a young engineer was about to enlarge a hole in the floor through which his main belt traveled, as it was running very unsteadily and striking the woodwork at nearly every revolution of the engine. Requesting him to postpone changing the size of hole, I applied an indicator and found that while the cut-off took place at nearly equal points in both strokes, one steam valve leaked so badly that the resulting diagram from that end was much larger

than that from the other, where the steam expanded according to the well-known laws.

The proper thing to do was to bore out the port and put in a new valve, but there are two things which often prevent making repairs that we know are needed, as they would produce better running machinery and save steam. One of these is the unwillingness of owners to expend money for

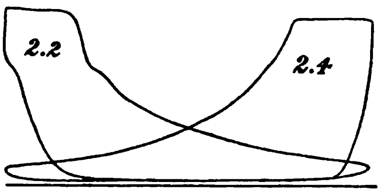

FIG. 1

this purpose, and the other is the undesirability of shutting down when orders are plenty and business is good. The consequence is that engineers are frequently obliged to resort to devices that will produce temporary improvement until more substantial repairs can be made.

Under these conditions it was deemed advisable to shorten the cut-off for the leaky valve, and lengthen it for the other until the areas of the resulting diagrams were equal, which produced regular speed of the engine, and made it unnecessary to enlarge the hole in the floor as the belt then ran very

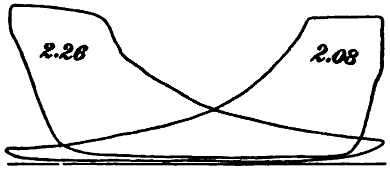

FIG. 2

steadily without touching the woodwork.

A heavy flywheel is usually considered desirable, as it assists in producing regular speed of machinery, but I found a case several weeks ago where the flywheel rim had evidently been made as light as the engine builder deemed safe to run, without consider-

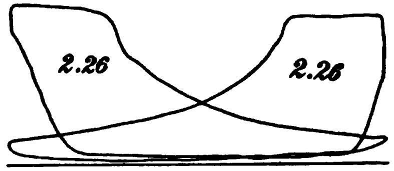

FIG. 3

ing any other point in connection with the matter. The result was that when the power developed was not the same for both strokes, the main belt showed it by "flopping" badly. An idler was bought and installed to hold the belt and make it run steadily. It accomplished the desired result, but was a needless expense to begin with and a nuisance ever afterward. This light flywheel illustrates the old saying which informs us that "there is no great loss without a small gain," for it

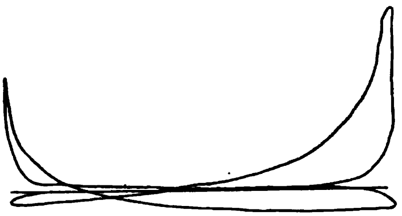

FIG. 4

pointed out the fact that the cut-off was not evenly set.

The bonnets were removed and the valves set by the marks as nearly right as possible, after which Fig. 1 was taken. The belt was running much better than formerly, but there was still chance for improvement. Fig. 2 was taken after another adjustment had been made, and it shows diagrams with nearly equal areas. The cut-off of one end was adjusted and Fig. 3 secured in which the areas are equal, and the belt was then running as steadily as any one could desire.

While these three pairs of diagrams

were being taken, the governor was held in position, as will be described later on. The idler was no longer required, which illustrates the fact that steam users sometimes spend money for articles that are not really needed, because they do not know just where the trouble is located.

Fig. 4 is a pair of diagrams taken from an engine with a cylinder 26 inches in diameter, located in one of the best equipped plants in the country. The right-hand diagram shows 14.5 pounds mean effective pressure, but the left-hand diagram indicates 6.5 pounds back pressure more than the forward pressure. If this engine were in a place where it was not properly cared for, this result might be charged to ignorance or neglect on the part of the chief

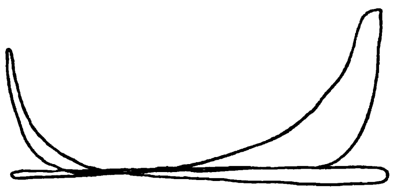

FIG. 5

engineer, but the high standing of this man among engineers, and the evidences found of careful and intelligent management elsewhere about the plant, forbids this solution of the problem; therefore, we must conclude that it was brought about intentionally.

This 6.5 pounds constitutes what might properly be termed the mean effective back pressure, as it is the total back pressure minus the forward pressure for that end of the cylinder. Subtracting this from the mean effective pressure of the other end, leaves a remainder of 8 pounds, which must be divided by 2 to get the mean effective pressure for both diagrams in order to calculate the horsepower in the usual way.

Fig. 5 is a pair of diagrams from a Corliss engine, in which the mean effective pressure of the right-hand diagram is 7 pounds, and the mean

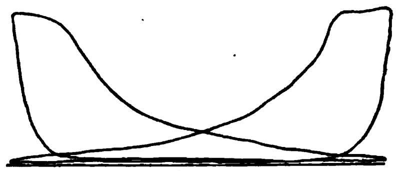

FIG. 6

effective back pressure of the left-hand diagram is 4 pounds; therefore, the mean effective pressure for the two together is 1.5 pounds. Attention is called to the fact that both Fig. 4 and Fig. 5 show a very light load, as in both cases the engine only is running.

After Fig. 5 was taken, the friction load of the shop was put on and Fig. 6 secured. The mean effective pressure of the left-hand diagram is 20 pounds, and of the right-hand diagram 22, or an average of 21 pounds for both.

When more load was put on, it produced Fig. 7, in which the mean effective pressure of the left-hand diagram is 38 pounds and of the right-hand diagram 35 pounds. This is about the average load on this engine, and at this point the cut-off is nearly the same for both strokes, and as it is quite evident that the points of cut-off do not remain relatively the same for varying loads, it is proper to have them agree for the average load, as this brings them right for a greater portion of the time.

These three pairs of diagrams show the engine just as it was running when

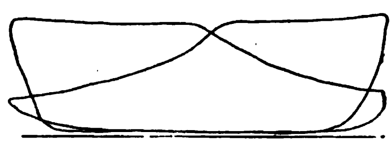

FIG. 7

each pair was taken, which is proper when it is desired to know the power developed under given conditions, but

it does not absolutely prove that the load was the same when both diagrams of each pair were taken. They do show, however, changes in the relative points of cut-off which are to be expected, and, therefore, are at least nearly correct, the only chance for error being the possibility of a change in the load between the two diagrams of a pair.

The rim of the flywheel on this engine was very heavy, and owing to the momentum of it, the two belts which it drives gave no evidence of the inequalities in the cut-off when Fig. 4 was taken, and this proves that a steady

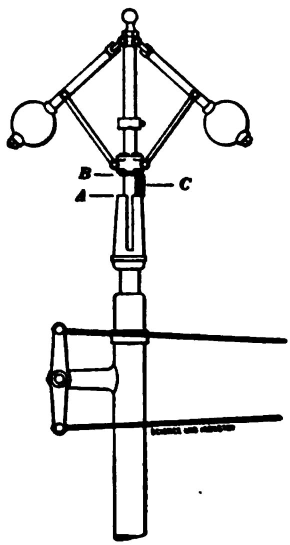

Fig. 8

running belt is no proof of a correctly adjusted cut-off gear. The steam valves were set properly, giving correct admission, but the left-hand diagram shows that the valve on the head end is tripped before all of the available initial pressure is realized. With the engine alone running it would be better if steam were admitted to the crank-end only, making it a single-acting engine as the head end acts as a brake under present conditions.

When the cut-off gear of an automatic engine is set so that diagrams from both ends have exactly the same area, which means that the mean effective pressure is equal, it takes into account any leakage that may occur after the cut-off valve closes; therefore, it is the best plan to adopt when properly executed.

Figs. 5, 6, and 7 were taken in order to determine the power required for various loads, without special regard to the way in which the cut-off gear was set, but Figs. 1, 2, and 3 were taken for the simple purpose of knowing whether the areas of the diagrams in each pair were equal or not. The plan adopted to accomplish this will now be described in a general way, for it applies to all automatic cut-off engines that are regulated by fly-ball governors, and it will show just what the engine is doing under a load that is known to be constant.

Note the position of the governor with an average load. It will answer the purpose of illustration to assume that the distance from A to B, Fig. 8, is 3 inches, although it may be either more or less than this in actual cases. Saw off a block of wood 3 inches long, and when the chief engineer is ready to take a diagram, let an assistant block the governor as shown at C in the illustration, and hold the sliding sleeve down on this block by taking hold of some part which can be moved but does not revolve. The diagram must be taken while this is being done, and the governor must be released immediately afterward, especially in cases where a change in speed is objectionable, as holding the governor out of its natural position may make a difference for a few revolutions.

When the chief engineer is ready to take another diagram, the same precautions must be observed, and when this is done carefully the results will

be reliable. If the areas of diagrams are not the same the cut-off gear should be adjusted so as to make them agree.

These diagrams are of no value for determining the power developed by the engine, except for those particular conditions, therefore they should not be used for trying to tell the power required by any particular portion of the machinery in the factory, as they are of value for setting the cut-off gear and nothing else.

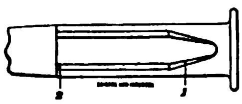

FIG. 9

While it is well to use an indicator for this purpose, if one is not at hand, the following plan will accomplish the same result, provided the valves do not leak.

Run the engine slowly and note the extreme travel of the crosshead in both directions, and mark it on the guides with a prick punch, or a fine cold chisel. See *1* and *2*, Fig. 9. This is assumed to be a Corliss engine, but the same principle applies to all disengaging valve gears. Stop the engine near the inside center, see that both valves are hooked up, raise the governor balls, put the block in place, as in Fig. 8, and turn the engine slowly until the hook is tripped and the valve closed by the dashpot. As soon as this takes place stop the flywheel instantly and measure the distance from *1* to the present position of the crosshead.

Turn the engine to the outside center and continue turning it very slowly until the other hook is tripped and the dashpot closes the valve on that end. Measure the distance traveled by the crosshead as before, and if it is the same on both ends the cut-off gear is correctly adjusted, but if one is longer than the other the tripping devices must be changed until the distances agree.

It is not practical to say which reach rod should be lengthened or shortened as that must be decided by the engineer according to conditions. If the governor balls are traveling in a low plane, the longer end should be adjusted to agree with the shorter, but if they are in a high plane, the shorter may be lengthened.

This will cause the cut-off valves to close at equal points in the strokes, and if the engine is in perfect order the area of the cards and the mean effective pressure indicated by each will be the same. It is not convenient to turn a large engine by hand for this purpose, but it is possible to do it in a majority of cases by admitting steam to the cylinder, although it requires practice to do it nicely. When this part of the work is finished it should be tested as follows: With the highest pressure on the boiler, and the lightest load on the engine, raise the governor balls as high as possible. If the steam is entirely shut off so that the engine stops, it is in a safe condition, but if it continues to revolve, the collar on the spindle must be raised, or one of the reach rods lengthened and the other shortened so as to shorten the point of cut-off on both ends.

The governor balls must be blocked in the position that they travel with an average load, because the fact that the cut-off is uneven for a light load does not prove that it is also uneven to the same extent with a heavy load, as Figs. 5, 6, and 7 demonstrate, therefore adjustments should be made that will give good results for the load that must be carried for a greater portion of the time.

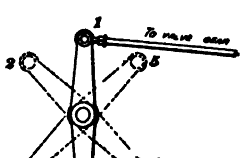

FIG. 10

The reason for this change under

varying loads is found in the following comparison and explanation:

If we place the crank of a horizontal engine on the inside center as a starting point, assume that the engine runs "over" and proceed to turn it in that direction until the crank stands vertical, we find that while the crank has traveled through the first quarter of a revolution, the crosshead has traveled more than one-half of the first stroke. Turning the crank through the second quarter and bringing it to the outside center, it naturally follows that the crosshead completes the stroke, but it has not traveled as far during the second quarter of the revolution as it did during the first. Turning it through the third quarter, the crosshead has traveled less than one-half stroke, and during the fourth quarter it travels more than one-half stroke. The same action occurs in the governing mechanism of the ordinary Corliss engine, as the same principles affect the result. Fig. 10 represents the double crank which imparts motion to the reach rods which operate the tripping devices. For convenience sake it is presented in a vertical position in full lines, representing the center of its travel, and in dotted lines it is shown at its extreme throw in both directions.

The full lines show its position with an average load. When the upper crank travels from *1* to *2* it represents the engine crank on the second quarter, during which the crosshead travels less than one-half stroke. At the same time the lower crank travels from *3* to *4* representing the engine crank during the third quarter of a revolution, during which the crosshead travels more than one-half stroke. When the travel is from *1* to *5* and from *3* to *6* the effect is reversed, which demonstrates that the tripping devices do not travel equally on either side of the central position shown, hence the points of cut-off will not be equal for a very heavy or a very light load, when they are alike for average conditions. The travel of the rods is exaggerated in the illustration in order to show the principle involved.

The result of this is that when the engine is started and brought up to speed slowly, one valve is tripped but the other is not, for the same position of the governor balls. The same inequality is apparent when a very heavy load is put on, and this forms an objectionable feature to some engineers, as they appear to think that the valves should be tripped alike at this time, but if the points of cut-off are the same now they will not be the same for an average load, and the latter seems to be the most desirable, because it gives good results for a greater portion of the time, as already described.

LINING UP SHAFTING

JOSEPH E. LEWIS. S. B.

THE engineering papers have contained numerous suggestions recently regarding the best method of putting up shafting. It is not the writer's intention, however, to review the various methods described, but rather to explain briefly a simple and accurate manner of securing good alinement in the vertical and horizontal planes. The following mentioned method seems to be known by very few engineers:

Referring to Fig. 1, *A* is a straightedge, which may be made from a piece of pine board about 4 feet long. It must be rigidly supported by uprights from the floor, or otherwise, as is most convenient, so that the top is at the height of the center of the shaft. Bring the straightedge to the true horizontal by the use of a spirit level and fix it securely in place. For short lines of shafting it may be located at one end, for long lines, at the middle. On each rafter that supports a hanger, nail a short stick *B*, with one nail, so that it may be swung up out of the way when not in use, as shown in Fig. 2. The bottom ends may all be brought into line by sighting carefully along the straightedge. For long lines sight in both directions from the middle. The ends of these sticks will all lie in the same horizontal plane at the height of the center of the shaft.

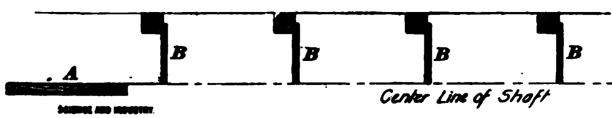

FIG. 1

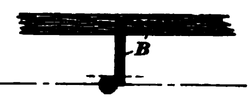

FIG. 2

The hangers may now be put up and the shaft placed in position and adjusted to the true level by testing each bearing. For this purpose the sticks *B* may be turned down as shown in Fig. 2, and the center of the shaft brought to the level at each bearing. This may easily be done by the eye. To test the result, a small spirit level may be laid across the top of the shaft and a line drawn on *B* as shown. The distance from this line to the end of *B* should be just one-half of the diameter of the shaft. The sticks should be turned up out of the way and left where they are, so that the alinement may be tested at any time.

Having adjusted all of the bearings to the same horizontal plane, we may now test them in the vertical plane. This is easily accomplished, whether the pulleys are in position or not. We will suppose that they are, and that the shaft varies from 3″ nominal, at the middle, to 1½″ at the ends. Take two pieces of string and tie a nut to each end of each piece. Throw one piece over the shaft near the bearing at one end and the other piece at the other end. See Fig. 3. Now stretch a stout cord *C* from one end to the other, low enough down to clear the pulleys. The end of the cord should be brought exactly central between the two ends of the string hanging over the shaft. The weights may be kept from vibrating by allowing them to hang in a pail of water. A small pail of oil is better yet, since its greater viscosity more readily checks any motion. Having pulled the line *C* taut in the correct position, it is an easy matter to adjust each bearing by throwing the string with the nuts on the ends over the shaft at the bearing to be tested, and

adjusting the setscrews until the line *C* is exactly central between the two ends of the string.

You will notice that variations in the size of shafting do not hinder this operation in the least, as is the case when a line is stretched at one side and attempts are made to measure in from it to the shaft; and furthermore, the presence of the pulleys is no objection whatever. Any shaft may be tested in this manner during the noon hour, except where the belts interfere with the line *C*. Where this is the case sufficient time must be allowed to remove such belts as are in the way.

If the shafting was put up with sticks, as above explained, it may also be tested for the horizontal plane in a very few moments. If these sticks are

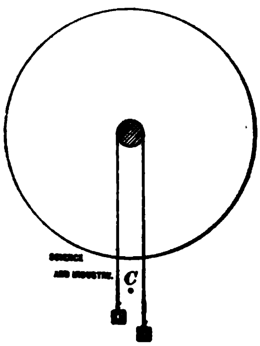

Fig. 3

not in position, and it is desired to test the alinement of a shaft already up, it is possible to run the line below the pulleys in the manner shown by Fig. 1, the ends of the sticks *B* being brought down to this plane. Now starting at any bearing the exact center of the shaft is marked on the stick. To be accurate a small spirit level may be used to mark across top and bottom,

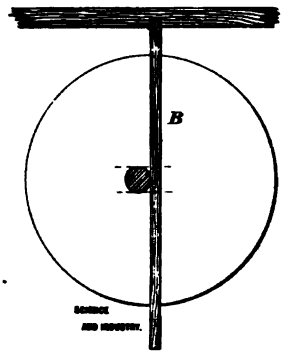

Fig. 4

see Fig. 4, and the space thus marked off divided in half to get the exact center. Measure carefully the distance to the end of the stick from this center line and cut a measuring stick to just that length. Use this to make a similar line on each of the other sticks *B*. One of these sticks will be located at each bearing and the center of the shaft may be readily brought to the line. All of the sticks may now be sawed off the right length and swung up out of the way for future use.

One should be cautious about always relying upon them, however, and if it is suspected that any portion of the building has settled since they were put up, they should be discarded, and a new line run.

ELECTRIC MOTORS AND THEIR APPLICATION TO DIFFERENT CLASSES OF WORK

CHAS. GRISWOLD

DESCRIPTIONS OF MOTORS—APPLICATION TO VARIOUS MACHINES

IN THIS advanced age of steam engineering, and with the advantages every English-speaking mechanic has to learn, the modern engineer should be in a position to advise any one who may consult him the conditions under which an electric motor is best suited to driving a piece of machinery, why it is best adapted to driving that particular piece of machinery, and the size and type most suited to the conditions; also the efficiency and saving that may be expected over other means of driving the machinery.

Leaving out the question of alternating-current motors, which are not so well adapted to intermittant-running machinery on account of their very weak starting torque, it leaves us with only one kind of motor to deal with, that is, the direct current motor.

Now let us go over the different kinds of direct-current motors and find out what their different characteristics are, so that we can more intelligently apply the different motors to the varied kinds of work they are called upon to perform.

We have but three kinds of direct-current motors to consider, the shunt-wound, the series-wound, and the compound-wound, which is a combination of the two previous windings.

It seems superfluous to illustrate and give an elaborate explanation of these three different windings, as they may be found in every textbook on the subject, a great many periodicals, and some catalogues, so we will simply discuss the effects of these different windings.

Starting with the shunt-wound motor: It has been said that the only difference between a dynamo and motor is that the dynamo has only one E. M. F. where the motor has two. The dynamo has only that E. M. F. which is generated in its armature. The motor has the applied E. M. F. and its C. E. M. F. which is in opposition to the applied E. M. F. It is this same C. E. M. F. that causes a shunt-wound motor, after it has attained a certain speed, to remain very nearly at that speed. When the current is applied to a shunt-wound motor, the field coils being shunted across the mains will have a constant amount of current flowing through them, consequently the field will be of constant strength regardless of other conditions, and as the armature starts to rotate there will be a C. E. M. F. generated in it, due to its rotating in a strong field, and as the armature increases in speed, the C. E. M. F. will increase until it will nearly equal the applied E. M. F., which only allows a small amount of current to flow through the armature, keeping it at a practically constant speed. If a load is now applied to the armature, it reduces the speed, which also reduces the C. E. M. F. and allows more current to flow through the armature, thereby doing more work at nearly the same speed. In other words the armature tends to remain at a practically constant speed regardless of the changes in load.

It will now be readily seen what a wide range of application the shunt-wound motor has, such as its connection to lathes, planers, drill presses,

ventilating fans, pumps, and all classes of mill machinery not requiring too great a starting torque.

A little explanation about starting torque is not out of place at this point. The stronger the fields, the greater the starting torque of the armature. As the pole pieces on a shunt-wound motor are never near the maximum strength to which they could be brought, we will consider the shunt-wound motor as having a medium starting torque, and not adapted to that class of machinery requiring a powerful starting torque.

We will now consider the series-wound motor, its good and bad points, and the class of work to which it is best adapted. A series-wound motor is one in which the field coil is made of sufficient carrying capacity to carry all of the current flowing through the armature. Being made of large wire it would naturally be of low resistance, making the motor as a whole of low resistance. If we apply an E. M. F. to the motor, there will be a large flow of current through it on account of its low resistance, and all of this current will be flowing through the field coils, thereby making them very strong and giving the armature a very powerful starting torque, which enables it to start under very heavy loads compared with the shunt-wound motor. Now, suppose the armature was not loaded, what would happen? As the armature increased its speed, the counter E. M. F. would rise, opposing the applied E. M. F., which would reduce the current. The reduction of current would reduce the strength of the field, the weakened field would reduce the C. E. M. F. without reducing the speed of the armature. In other words we would not be able to generate C. E. M. F. enough to oppose the applied E. M. F. Consequently we could not reduce the current enough to keep the armature from runing away. The result would be, the armature would increase to such a speed that it would destroy itself by centrifugal force. This is the bad point about the series-wound motor.

It can now be plainly understood why the series-wound motor is best suited for use in connection with street cars, automobiles, elevators, freight lifts, lead presses, or any class of machinery that may require a powerful torque at low speeds.

We will now discuss the characteristics of the compound-wound motor, which is nothing more or less than a combination of the other two windings. It partially overcomes the faults of the other two windings. The compound-wound motor is used very extensively for elevator work, giving a fairly good starting torque, and having the advantange of a fairly good field strength at all times, due to the shunt coils.

In some classes of elevator work, where the car comes down of its own weight, due to the counter weights being considerably lighter than the car, the motor is run by the weight of the descending car. The motor is used as a brake upon the car by turning it into a generator. The shunt coils keep a constant strength of field, and the armature and series-coils are short-circuited across a variable resistance. As the resistance is reduced the motor acting as a generator sends more current through the short circuit and the speed of the car is thereby reduced. As the resistance is increased, the motor acting as a generator sends less current through the short circuit and speeds up due to the weight of the descending car, so there is a perfect control of the speed of the descending car.

Any one of these three motors is

reversible, that is, it can be run in either direction. With the modern carbon brushes set at right angles to the commutator they can be provided with a reversing switch, so that they can be reversed as often as necessary to suit the machinery.

The compound motor can also be connected up for constant speed, if the series-winding has been properly proportioned, and is connected the reverse of the shunt winding, so that as the armature takes more current it will weaken the field, consequently the armature will speed up, or in other words, will maintain a constant speed for wide variations in load. But under these conditions it loses its other good quality of being able to start a very heavy load.

One very important quality of the electric motor is its ability to stand excessive overloads for short periods of time, and medium overloads for long periods, like an all day run. Certain classes of machinery require a variable amount of power, such as the metal plainer, with its reversible bed, requiring in some cases, where the planer is heavy, more power to reverse and run the bed back with its increase of speed than it does to run the cutting stroke. For all kinds of punching machinery, some forms of hydraulic machinery, and all cases where a fluctuating amount of power is used, the motor need be calculated for only the average amount of power used on the machine.

In the method of applying the motor to the different classes of machinery, there are several conditions that have to be taken into consideration. First, what part of the machine the power is to be applied to; if the motor can be fastened to the solid parts of the machine, or put on the floor, or suspended from the ceiling, or bracketed to a nearby wall. Second, the speed at which the driving parts of the machine have to be driven. Third, the amount of power the machine requires to drive it.

Take the first condition into consideration, assuming that the machine is to be driven by an individual motor. If the motor can be fastened to the side or some part of the machine, and drive it either directly or through good cut gears, always maintaining perfect alinement, in fact being a part of that machine, which occupies a minimum amount of floor space, with a clear space over head, not obstructing the light, and allowing the use of cranes for handling the work, it will be found preferable to any other means of applying a motor.

If the conditions will not permit the motor to be fastened permanently to the machine, the next best solution of the problem is to fasten the motor to the floor, and drive by gears, if possible. If not, then by belts, or fasten the motor to tne ceiling or to the side wall and drive by belt. I do not approve of the use of belts where the conditions will permit of direct connection, or cut gears, for belts, as they are generally found under running conditions, are the source of a large amount of wasted energy, due to friction caused by being too tight, or slippage, caused by being too loose, air resistance and cushion, creeping, and the resistance of the leather to bending and straightening several hundred feet of it per minute.

The second condition we meet is the speed at which the machine is to be driven. If the machine is of high speed, it can be driven directly by the use of a bipolar motor. If of medium speed, use a multipolar motor designed for that speed, also connected directly, thereby gaining the greatest combined

efficiency of motor and transmitting gear. If of low speed, use reducing gears or belts and countershafts. I could not recommend the use of a worm and worm gear, except in special cases where a very small amount of power is to be transmitted with a large reduction of speed, or where space is very limited, as they are of low efficiency compared with a spur gear.

The third condition we have to deal with, is the amount of power required to drive the machine. This is a case of selecting a motor of fairly high efficiency to do the work of several small motors of low efficiency. Take the case of several small machines requiring a fraction of a horsepower each. If each machine were equipped with a small motor of low efficiency, then we would have a low combined efficiency for the group of small machines. Just how many of these small machines we would group together and run from a short section of shaft driven from one motor would depend on how much each machine was to be run each day and how many of them would be running at the same time. There can be no general rule laid down covering such cases. Each case must be studied and arranged according to the conditions your judgment tells you will give you the best efficiency, grouping the machines together that are to be run the most, in such numbers as will require an average of one horsepower at least, and two horsepower would be better. If the machines are to run only an hour or two a day, it would be better not to group them at all, but put individual motors on each, for the gain from having a small low efficiency motor, not using any current several hours a day, would overbalance any saving we might make by using a larger and more efficient motor, but having to run it one-half or three-quarters of the time.

As a guide to the efficiency of different sized motors, I will give the efficiencies generally found in the following sizes: $\frac{1}{4}$ to $\frac{1}{2}$ H. P., 40 to 50 per cent.; $\frac{1}{2}$ to 1 H. P., 50 to 60 per cent.; 1 to 2 H. P., 60 to 75 per cent.; 2 to 3 H. P., 75 to 85 per cent.; 3 to 5 H. P., 85 to 90 per cent.; 5 to 10 H. P., 90 to 95 per cent.

Also, as a guide to the power required to drive machine tools, I will give you the results of a test made by Prof. Crocker at the Crocker-Wheeler Electric Co. shop at Ampere, N. J.

Test No. 1. Large boring machine driven by a $1\frac{1}{2}$ H. P. motor. Power consumed in current was 8.3 amperes at 110 volts = 1.23 H. P. average.

Test No. 2. Drill press run by 1 H. P. motor. The average current was 2.92 amperes = .41 H. P.

Test No. 3. Another drill press, = .42 H. P.

Test No. 4. Another drill press, = .28 H. P.

Test No. 5. Punch press, average .71 H. P.

Test No. 6. Gang drill (3 drills), $\frac{1}{4}$-inch holes, .7 H. P.

Test No. 7. Group, one lathe and one milling machine driven by 3 H. P. motor, belted to short line shaft, both tools cutting, 2.28 H. P.

Test No. 8. Group of six machines, 2 lathes, 1 milling machine, 1 grindstone, 1 drill press, 1 punch press, average for several hours, .86 H. P.

Test No. 9. Group of seven machines, 1 planer, 1 grindstone, 4 lathes, 1 hand lathe, average power 1.97 H. P. Entire lot in use 2.65 H. P.

Test No. 10. Group of 7 lathes, 1 grindstone, average 1.46 H. P.

Test No. 11. Group of two machines, 1 large punch press, 1 large

planer, punch press not used during test, average 4.87 H. P. 47 per cent. being required to drive shaft and belt overhead from motor on the floor.

Test No. 12. Group of 20 machines, 8 lathes, 4 milling machines, 3 planers and shapers, 2 grindstones, 1 vertical grinding machine, 3 small tools. Average number of machines running was 13. Average power for one afternoon 4.78 H. P.

Test No. 13. Group of 5 machines run by 3 H. P. motor, 4 lathes 17 inch, 14 inch, 12 inch swing, 1 slotter, average 1.03 H. P.

Test No. 14. New 50-inch swing lathe driven by 3 H. P. motor, turning and facing $5\frac{1}{2}$ inch steel shaft, average 1.68 H. P.

There are numerous instances where a change has been made from a long line of shaft and a great many belts to motor-driven machinery with a great saving over the old method. There is also a large field for electric motor-driven pumps to take the place of steam-driven duplex pumps that require 150 to 350 lb. steam per horsepower hour delivered. There are a great many other cases where the electric motor might be advantageously applied, and time and experience will force that fact upon the minds of the mechanic and electrician very soon in this age of rapid progress.

REVERSING AN ENGINE

AT FIRST thought this operation would perhaps seem too simple to permit of an explanation of any considerable length and possibly unworthy of illustration. With many engineers this is no doubt true, at the same time there are those who cannot or at least do not understand why the center of the eccentric, when the engine is reversed, should not be diametrically opposite its first position. Perhaps the simplest rule for reversing an engine is the following: When reversing the direction of rotation of an engine fitted with a direct valve gear, the eccentric should be turned around on the shaft approximately one-fourth of a revolution and in the opposite direction to which the engine is to run, the exact amount depending on the lap and lead of the valve. The point which

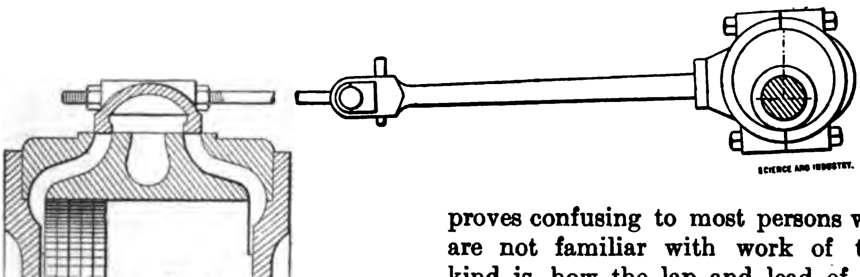

Fig. 1

proves confusing to most persons who are not familiar with work of this kind is, how the lap and lead of the valve affects the position of the eccentric. The prevailing idea apparently is that if the eccentric occupies a certain position, for instance when the engine runs "over," when the direction of rotation is to be reversed the position of the eccentric should be exactly opposite its first position. In certain cases this will be found to be correct, but it is not true in the

majority of steam engines in actual service. When a valve has no lap, that is, when the outer edges of the valve do not extend beyond the outer edges of the steam ports when the valve occupies the position of mid-travel, the eccentric must be moved straight across the shaft, that is to say, it must be turned around on the shaft through one-half of a revolution in order to cause the engine to run properly in the opposite direction, whether the valve is given lead or not.

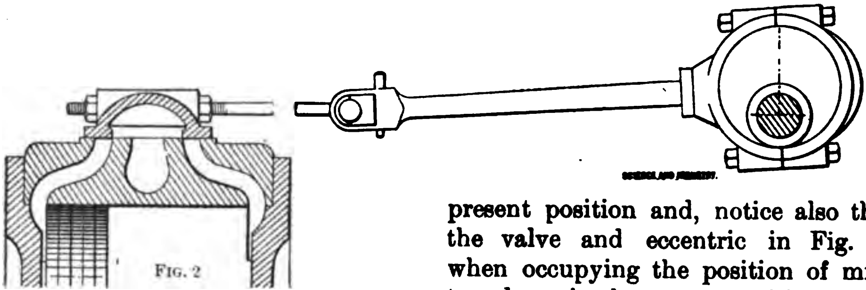

FIG. 2

Referring to Fig. 1 it will readily be seen why this is so. The valve rod is represented as having been broken and the eccentric turned around, bringing the crank somewhat out of line so that the position of the center of the full side of the eccentric relative to the valve might be more clearly seen.

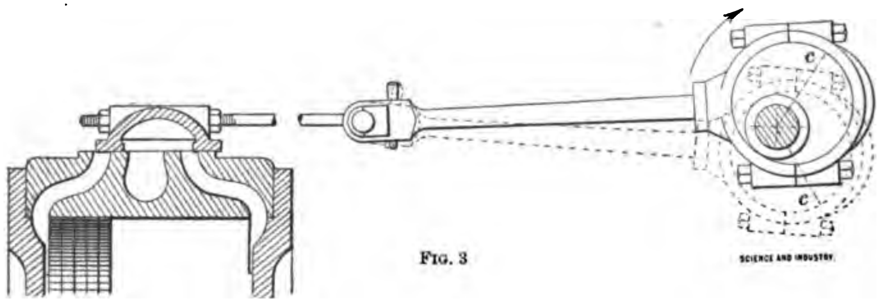

FIG. 3

The valve in this illustration has no lap and occupies the position known as mid-travel. It is apparent that the valve must move an equal distance in either direction from its present position in order to properly open the ports. As the valve receives its motion from the eccentric, it will also be apparent that the eccentric must move an equal distance in either direction from its present position and, notice also that the valve and eccentric in Fig. 1, when occupying the position of mid-travel, are in the proper position at the commencement of the stroke of the piston. Now, it will be seen that when the eccentric is turned through exactly one-half of a revolution it will occupy the correct position at the commencement of the stroke when running in the opposite direction. This proves that when referring to valves which have no lap, the idea prevailing among many engineers is strictly correct.

Now let us consider the movements of an eccentric connected to a valve having lap. When placed in the position of mid-travel, as in Fig. 2, it will be seen that both the valve and eccentric must move an equal distance in either direction in order to properly open the ports, but the valve is not in the position it should be at the

commencement of the stroke of the piston, for the simple reason that it is not now in a position to open the ports for the admission of steam. The valve laps over the outer edges of the ports, and in order to have it ready to open the port it must be drawn either

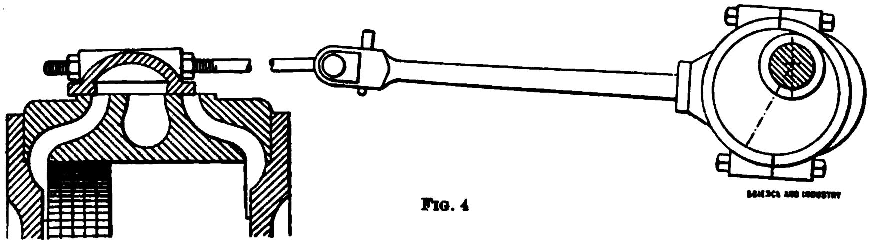

Fig. 4

to one side or the other a distance equal to the lap.

Fig. 3 shows the valve as having been drawn to the right and also illustrates the corresponding position of the eccentric.

While both valves in Figs. 1 and 3 are in position to open the port when slightly moved, only one of them (Fig. 1) is in its position of mid-travel; this change of position being necessitated by the lap of the valve in

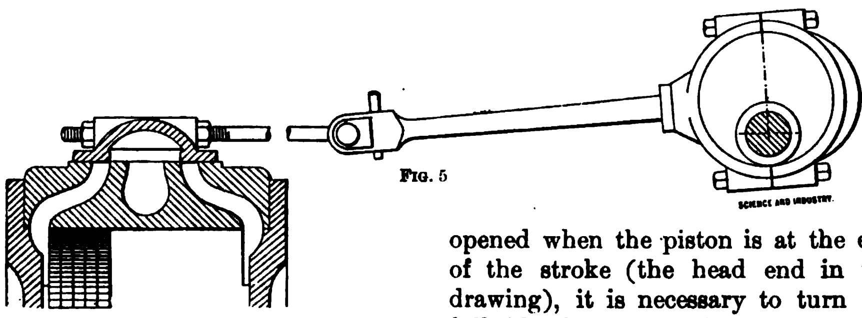

Fig. 5

Figs. 2 and 3. Now let us turn the eccentric in Fig. 3 through one-half of a revolution and see what the result will be. The center of the full part of the eccentric will then stand directly opposite the first position, as shown in Fig. 4. Note the position of the valve. If steam should now be admitted it would hold the piston (and the crank) in its present position and the engine could not be started at all, because the valve has opened the opposite port in Fig. 4. One would be apt to conclude that if this port were opened the direction of rotation ought to be reversed, and when the crank (and piston) occupies any other position than the dead center this will hold true, so far as being able to move the piston is concerned, but when the piston is at the end of the stroke, the valve must open the same port that is open in Fig. 3, whether the eccentric is set to run either "over" or "under." Now, in order to fulfil these conditions, viz., that the same port may be opened when the piston is at the end of the stroke (the head end in the drawing), it is necessary to turn the full side of the eccentric in Fig. 3 in the direction of the arrow and until the valve opens the port wide and closes it again to the amount of the lead. The eccentric will then be in the position shown by the dotted lines, Fig. 3. Note the position of the eccentric. It has been moved around on the shaft through

approximately one fourth of a revolution, which tends to prove the directions previous' given to be correct.

We now come to the clause: the exact amount will depend upon the lap and lead given the valve. Turn for a moment to Fig. 5. Here we have a valve with more lap than in Fig. 3. When this valve occupies the proper position at the commencement of the stroke of the piston, the eccentric will have been turned to the right, as indicated by the full lines in Fig. 6, and when the direction of rotation shall have been changed it will occupy the position shown by the dotted lines in the same figure.

It will now be noticed that the distance, or more correctly, the angle included between the eccentric centers *c c*, shown in Fig. 3, is greater than that indicated in Fig. 6, although the valves have opened the ports the same amount in both cases, namely the width of the lead. It will be understood therefore that the difference between the angles referred to is caused by one valve having more lap than the other; the eccentric having been turned farther away from the cylinder in Fig. 6 in order to open the port, and this proves that the exact position of the eccentric or the exact amount which it must be turned around on the shaft will depend upon the amount of lap and lead given the valves, because the lead is equivalent to an equal amount of lap, so far as the position of the eccentric is concerned.

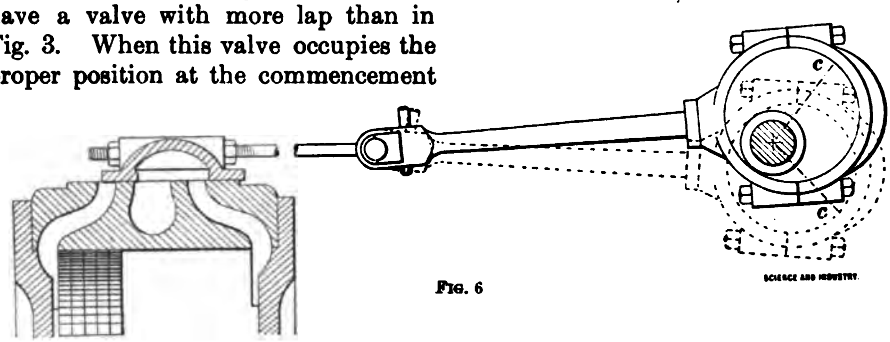

FIG. 6

One might conclude that a person could easily determine the position of the eccentric when the valve is given any amount of lap, by laying out the gear on paper, and so he could, providing the points of the compasses are placed at the proper points, and thus consider the proper distances, but if the principles involved are not understood, how shall he know what points to lay out?

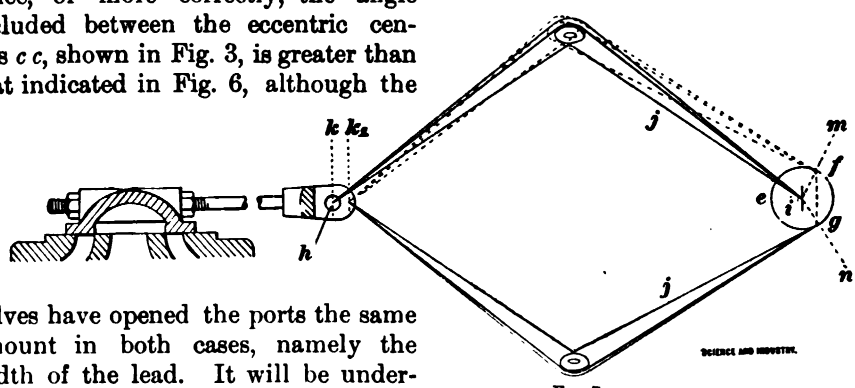

FIG. 7

It would be a good plan, for those who have not reversed an engine, to practice a little in laying out the

various positions of the eccentric due to different widths of lap and with varying lead. This may be done by first laying off the ports in the valve seat and then drawing a valve in the position of mid-travel. The full travel of any valve is equal to twice the width of one steam port plus twice the distance that one end of the valve laps over the outer edge of the steam port. Having the travel of the valve, lay off a circle *efg*, Fig. 7, whose diameter is equal to the given travel. Now place one point of the compasses at the center of the knuckle pin *h* and the other point at the center of the circle *efg*, or the center of the shaft, as shown at *i*. We now have between the points of the compasses the true length of the eccentric rod. Most engineers know that the working or true length of the connecting rod is measured between the centers of the wrist and crank-pin boxes in the rod and not between the extreme ends of the rod. Likewise the true length of an eccentric rod is measured between the centers of the pins; the center of the eccentric taking the place of a pin at this end.

Now measure off the lap of the valve plus the lead $k\,k_1$ Fig. 7, which will locate the center of the knuckle pin when the valve has opened the port to the amount of the lead. Place one point of the compasses at the center k_1 and the other on the circumference of the circle *efg*, as shown. This will locate the center of the eccentric when the valve occupies the proper position at the commencement of the stroke of the piston. Swing the leg *j* across the circle, as indicated by the dotted line, until it touches the circumference at the opposite side. This will locate the center of the eccentric when the direction of rotation is reversed, and by drawing the radial center lines *m* and *n*, the angle, or the distance through which the eccentric must be moved, may be accurately determined.

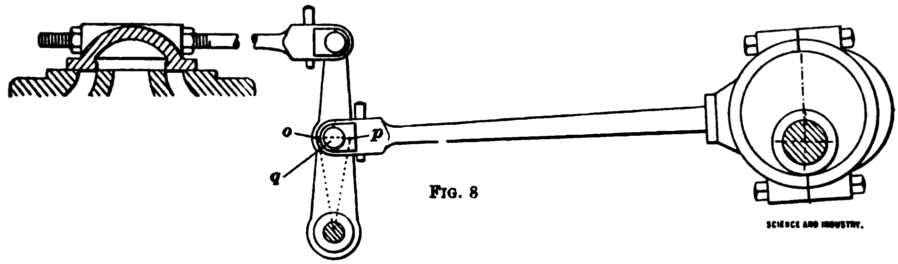

FIG. 8

Some reader may ask: What about the measurements when the gear shown in Fig. 8 is employed? The principle in this case is the same, and it will make no difference whether the travel of the valve is multiplied much or little, because as far as the eccentric is concerned the travel is measured at

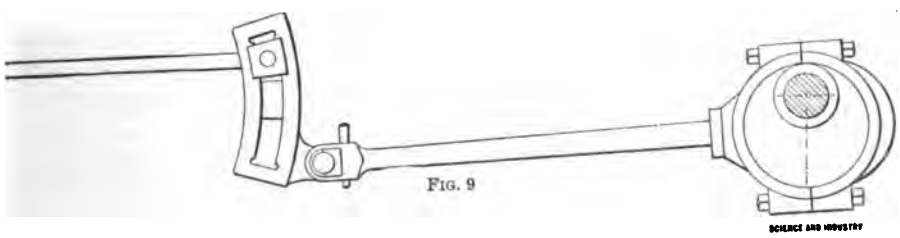

FIG. 9

o p when finding the true length of the eccentric rod, the center of the pin *q* then takes the place of the pin *h*, in Fig. 7, and it should be in the position of mid-travel, as shown, when making the measurements referred to. If the stroke of the valve is assumed to be twice that of the pin *q*, then, when setting the compasses, only one-half of the lap, plus the lead, must be measured off from the center of the pin *q* instead of the full amount, as at $k\ k_1$ in Fig. 7. This is the only difference in the methods used in the two cases.

Any one who has had occasion to look over the patent records with a view of securing information pertaining to valve gears, cannot fail to be impressed by the great need of a more systematic study and a clearer understanding of the simple valve gear herein illustrated, by inventors of steam engines and valve gears.

A large number of inventors have made use of the simple mechanism shown in Fig. 9 to reverse their engines (though not necessarily included in the patentable portion of their inventions), and while it appears to be a correct as well as a simple mechanism, particularly to those unacquainted with valve gears, it is not at all practicable in connection with a valve having lap.

This gear will afford a good opportunity for practice in laying out and proving the impracticability of certain arrangements, as well as the relative position and movements of the valve, eccentric, and crank (or piston), which may be done by the method just described.

Make the diagram as large as possible, use well sharpened pencils, employ regular drawing paper, and, if the work be carefully executed, the result will prove reliable.

WHAT THE INDICATOR DIAGRAM TELLS US

CHAS. L. HUBBARD

We are apt to think of the indicator diagram simply as a means of computing the horsepower of the engine from which it was taken, and to overlook entirely the other interesting and valuable information which a careful inspection of the diagram will often reveal.

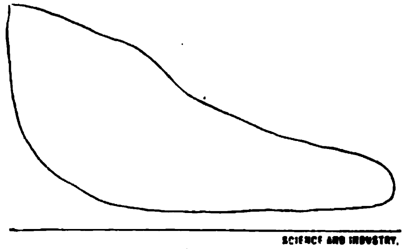

FIG. 1

Sometimes an engine appears to run well, and the owner is perfectly satisfied with it, but a careful study of the indicator diagrams may show that considerable saving might be made by correcting defects in the valve setting.

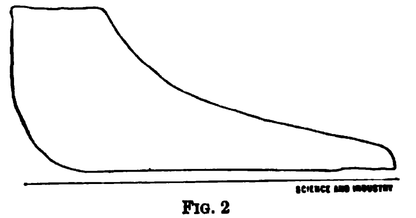

FIG. 2

On looking at a diagram one might say at first sight that it was a faulty card, and yet for the given type, size and speed of engine, it may be the best that can be obtained. This is well shown in Figs. 1 and 2, the first of which was taken from a simple non-condensing 6″ × 8″ engine having a

plain slide valve and running at a speed of 210 revolutions per minute. The second was taken from the high pressure cylinder of a compound engine having a Corliss valve gear and running at a speed of 85 revolutions. The most common faults in the distribution of steam in the cylinder may be divided into four classes, as follow: Too early or too late admission; too early or too late cut-off; too early or too late release; and too early or too late compression.

In the following figures let *A* be the point of admission; *B* the point of cut-off; *C* the point of release; and *D* the

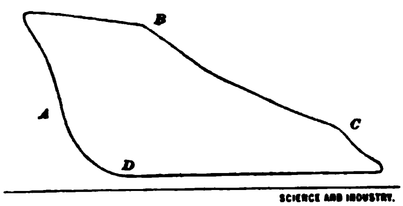

FIG. 3

point where compression begins. In Fig. 3 the card shows too early admission. The admission line curves backward instead of being straight and perpendicular to the atmospheric line as it should be. The diagram also shows cut-off, release, and compression too early. In the case of the plain slide valve all of the events are likely to be too early if one of them is. A diagram of this kind shows too much angular advance, and can be remedied by shifting the eccentric backward on

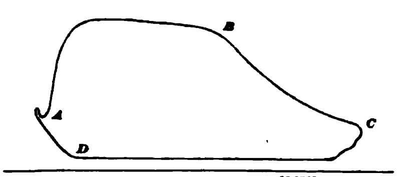

FIG. 4

the shaft. Fig. 4 shows a diagram having the opposite defects to those in Fig. 3. The events are too late, the admission line curves forward and shows that admission does not take place until after the stroke is well begun. Release occurs at the end of the stroke. In this case the eccentric should be

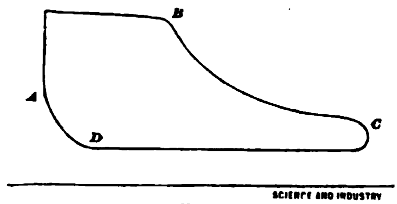

FIG. 5

moved forward until the admission line is perpendicular to the atmospheric line. Fig. 5 shows a card having too much back pressure. This may be due to small exhaust ports or pipe, or the passage of steam through pipes for heating. In other ways the card shows good distribution of steam. Fig. 6 shows a card in which the cut-off occurs too late and the pressure is high at release. When an engine runs under this condition much of the steam is wasted due to the small amount of expansion The diagram shown in

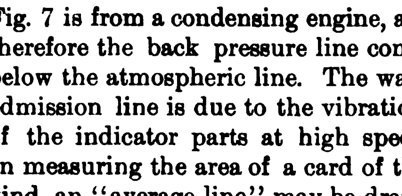

FIG. 6

Fig. 7 is from a condensing engine, and therefore the back pressure line comes below the atmospheric line. The wavy admission line is due to the vibrations of the indicator parts at high speed. In measuring the area of a card of this kind, an "average line" may be drawn in, as shown by the dotted line, and this may be taken as the true outline of the diagram. Fig. 8 shows a pair of diagrams taken from a plain slide-valve engine. The admission lines are good, but the sloping steam lines show wiredrawing due to the slow action of

the valve or too small ports or steam pipes. This wiredrawing decreases the area of the card and indicates a loss.

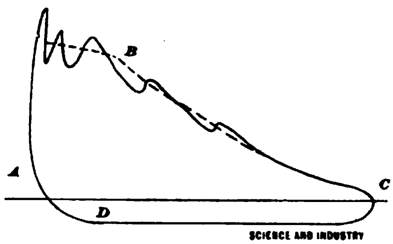

FIG. 7

The greatest fault shown is the inequality of the cards for the two ends of the cylinder. The late cut-off, and consequent late compression of one end, causes more area on that card than the too early cut-off and too early compression of the other. These cards can be improved by adjusting the angular advance of the eccentric and the length of the valve rod.

The diagram in Fig. 9 indicates too early compression, the compression

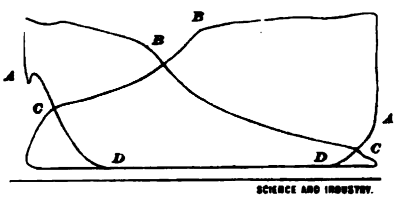

FIG. 8

curve extending above the initial pressure line. The area of the loop must be subtracted from the card area when computing the indicated horsepower. If the cut-off is kept the same and the compression made what it should be, the gain in area would be that included between the full line and the dotted line, plus the area of the loop. The remedy for this case is to increase the inside lap. The amount of compression varies with the speed and type of engine. Slow-speed engines require less compression than high-speed engines. The exhaust remaining in the cylinder should never be compressed higher than the initial pressure. For high-speed engines the compression should extend to about .9 of the initial pressure. For medium speed about .5, and for low speed from .2 to .4. In the case of a slide-valve engine it is not always possible to set the valve so that the card will have all the events as they should be. Sometimes it is necessary to change the laps of the valves. For too much compression, decrease the inside lap. For too early cut-off, decrease the outside lap. If the valve travel is increased, compression is de-

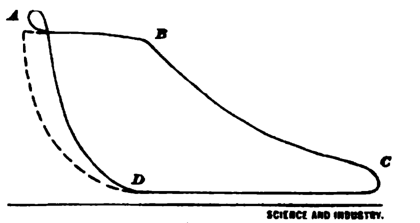

FIG. 9

creased, and release is also retarded. Another use of the diagram is in the determination of losses in the cylinder due to leaky valves and cylinder condensation. The amount of these losses may be found by weighing the water fed to the boiler, and by condensing the exhaust steam for a given length of time, and then subtracting from this the amount shown as doing useful work by the indicator diagram. The

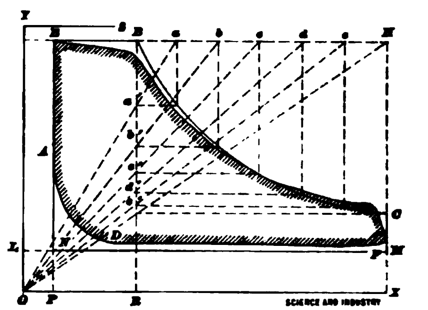

FIG. 10

difference between the water consumption shown by the actual weighing of the feedwater and by computation

from the card will give the losses due to leakage and condensation.

The diagram shows by direct measurement the pressure and volume at any point in the stroke of the piston. The weight per cubic foot for any given pressure may be taken directly from a steam table. The method, then, of finding the weight of steam for any point in the stroke is to find the volume in cubic feet, including the clearance and piston displacement to the given point, which must be taken at cut-off or later, and to multiply this by the weight per cubic foot corresponding to the pressure at the given point measured on the diagram. This will give the weight of steam in the cylinder. As this weight includes the steam used for compression, it must be corrected as follows to obtain the weight used per stroke. Take some point on the compression curve and measure its absolute pressure. Then compute the weight of steam to this point. Subtract this weight from the weight of steam to the point taken in the expansion curve, already computed, and the result will be the weight of steam used per stroke. The best point on the expansion curve to use for this purpose is just before release. This is true for two reasons: first, the maximum amount of leakage has had a chance to take place, and second, a certain part of the steam which is condensed during admission and the first part of the stroke is reevaporated into steam and does useful work toward the latter part of the stroke. This is shown in Fig. 10, in which the shaded curve represents the actual expansion line and $B\,C$ the theoretical line. The actual line falls below the theoretical during the first part of the stroke, showing condensation and drop in pressure, and rises above it during the latter part of the stroke, showing reevaporation and a rise in pressure above that shown by the theoretical line.

The actual computation of the steam consumption from an indicator diagram is best illustrated by working a practical example.

Let Fig. 11 represent a diagram

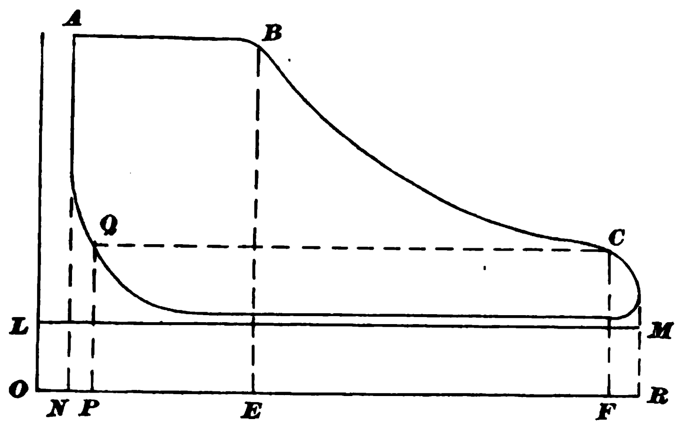

FIG. 11

taken from a 20″ × 36″ engine running at a speed of 80 revolutions per minute. The card was taken with a 40-pound spring. By measurements we find the mean ordinate to be .91 inch and the M. E. P. $= .91 \times 40 = 36.4$ pounds. The I. H. P.

$$= \frac{36.4 \times 3 \times 314 \times 160}{33{,}000} = 166 +.$$

In Fig. 11 $L\,M$ is the atmospheric line, and $O\,R$ the line of zero pressure drawn so that $O\,L = 14.7$ pounds. $O\,N$ is the clearance volume $= 8$ per cent. of the piston displacement. The line $P\,Q$ is drawn from $O\,R$ to some point on the compression line. From

C, a point on the expansion line just before release, the line CF is drawn perpendicular to OR. Then, measuring from the diagram, we have

$OR = 3.24$ inches;
$OF = 3.00$ inches;
$OP = .375$ inches;
$CF = .795$ inches;
$PQ = .795$ inches.

The length of stroke is 36 inches or 3 feet, and the length of the diagram 3 inches. Then, 1 inch of the length of the card corresponds to 1 foot of the stroke. The scale of the spring used is 40. Therefore we can easily reduce the above dimensions to pounds pressure, and to feet, which gives the following results:

$OR = 3.24$ feet;
$OF = 3.00$ feet;
$OP = .375$ feet;
$CF = 31.8$ pounds;
$PQ = 31.8$ pounds.

The area of the piston is 314 square inches or 2.18 square feet.

We can now find the volume of steam at any point of the stroke. When the piston is at C, the volume is $2.18 \times 3 = 6.54$ cubic feet. When the piston is at Q, the volume is $2.18 \times .375 = .8175$ cubic feet. From a steam table we can find the weight of a cubic foot of steam at any given pressure.

The weight of 1 cubic foot of steam at 31.8 pounds absolute is .0777 pounds. Then, the weight of steam present when the piston is at C is $6.54 \times .0777 = .5081$ pounds. The weight of steam present when the piston is at Q is $.8175 \times .0777 = .0635$ pounds.

The weight of steam in the cylinder at release is .5081 pounds and the weight kept for compression .0635 pounds. The weight exhausted per stroke is therefore $.5081 - .0635 = .4446$ pounds. This quantity multiplied by the number of strokes per hour will give the weight of steam to be accounted for by the diagram, and this subtracted from the actual weight of feed water used during this time will give the cylinder wastes due to condensation and leakage.

The method of constructing the theoretical curve referred to in Fig. 10 is as follows: Draw PX equal to the length of the stroke, and OP equal to the clearance, shown as a per cent. of the piston displacement. Draw OY and PE perpendicular to OX and draw YS parallel to OX and at a height corresponding to the boiler pressure. The line of initial pressure EB is then drawn parallel to YS and is usually taken from 90 to 95 per cent. of the boiler pressure if there is no especial cause for loss.

Then take EB as the portion of the stroke at which steam is admitted so that $\frac{PX}{EB}$ = the ratio of expansion. The expansion line is considered as a hyperbolic curve with OX and OY as asymptotes. To construct the curve first draw the line EBH parallel to the atmospheric line and FH and RB perpendicular to it. Then make points a, b, c, d, and e, on BH and connect them with the point O. At the points a', b', c', d', and e', where these lines intersect the line RB, draw parallels to BH until they meet perpendiculars from a, b, c, d, and e.

The points of intersection of these lines are points on the hyperbolic curve BC as shown in Fig. 10. Any number of points may be used but there must be enough to determine the curve.

USE OF STARTING BOX FOR SHUNT MOTOR

WM. GRATZ

DANGER DUE TO EXCESSIVE CURRENT—CONSTRUCTION OF STARTING BOX — CONNECTIONS TO MOTOR AND MAINS—EFFECT OF COUNTER E. M. F.—OVERLOAD STARTING RHEOSTAT

WHEN starting a shunt motor it is necessary to insert resistance in the armature to prevent an excessive current rushing through the armature and burning it out. After the motor has speeded up its counter E. M. F. will keep the current down and the resistance may be removed from the armature circuit. A current too large for the carrying capacity of the conductors is liable to flow through the armature if it is connected directly across the mains, because the resistance of the armature itself is very small. Thus suppose the resistance of a certain motor armature is 0.5 ohm, and that the motor is to be run from 220 volt mains. By Ohm's Law the current flowing through this motor, if it were connected directly across the mains, would be

$$C = \frac{220}{0.5} = 440 \text{ amperes.}$$

To reduce such an excessive rush of current through the motor when starting it, a resistance is connected in

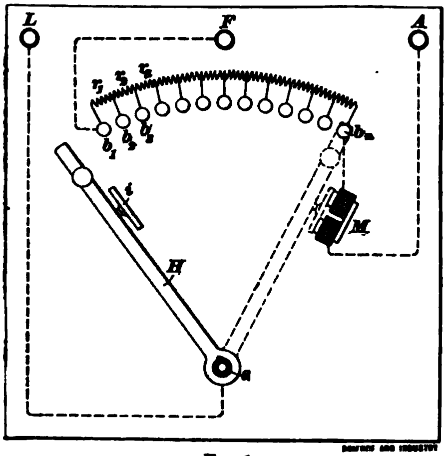

FIG. 1

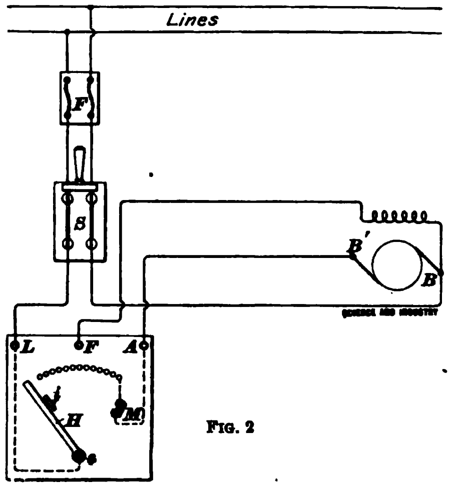

FIG. 2

series with its armature; and this resistance is gradually cut out as the motor speed comes up. To accomplish this result is the duty of the starting box.

The starting box consists essentially of a number of resistance coils connected in series and some device whereby this resistance can be gradually cut out as the motor speeds up until finally when the motor is running at its normal speed it is all cut out.

Fig. 1 shows the construction and circuits of a very simple form of starting box. *L*, *F*, and *A* are binding posts; r_1, r_2, etc., are resistance coils; b_1, b_2, etc., are brass contact pieces to which the ends of the coils r_1, r_2, etc., are connected. *M* is an electromagnet to hold the lever *H* in the position shown by the dotted outline by means of the soft-iron armature *i*. At *s* is a spring which brings the lever back to the left when the circuit through the magnet is broken by opening the switch or otherwise. Fig. 2 shows

how the motor is connected through the box. One terminal of the field winding is connected to the binding post F; the other terminal of the field is connected to one of the brushes. The brush B to which the field terminal is directly connected is in turn connected to one of the mains, M, through the switch S and fuse block F. The brush B' is connected to the binding post A. The binding post L is connected to the other main through the switch and fuse block. To start the motor switch S is closed; then H is moved to the right. When H comes in contact with button b_1 (Fig. 1), the armature and field circuits are both

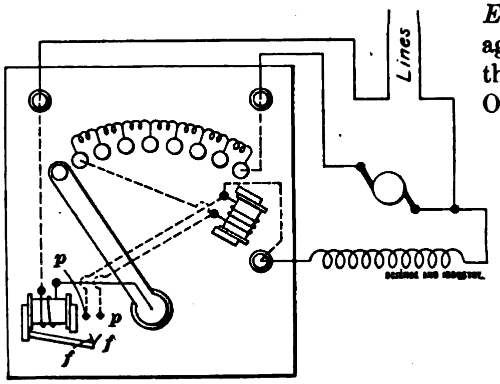

FIG. 3

closed and current, therefore, flows through them. But to get to the armature the current must flow through the resistance coils r_1, r_2, etc. To get to the field, on the other hand, the current goes directly from b to binding post F, then to the field winding. A very strong field is therefore set up immediately. As the lever is moved further to the right, say to b_3, the resistance coils r_1 and r_2 are *cut out* from the armature circuit and *cut into* the field circuit. And as the field current is decreased the motor speeds up and its counter E. M. F. increases. When the handle has finally been moved to its extreme position ("full on") to the right, making contact with b_n, it is held in that position by the pull of the electromagnet M on i. In this position all the resistance is cut out of the armature circuit. The counter E. M. F. now accomplishes what the resistance coils accomplished before, but in a somewhat different manner. The coils r_1, r_2, etc. kept the current in the armature down by their resistance; the counter E. M. F. keeps the current down by decreasing the force that is pushing current through the armature, i. e., it lowers the *available* E. M. F. The available E. M. F. is equal to the line E. M. F. minus the counter E. M. F. If E is the voltage across the mains, and E' is the counter E. M. F. then the voltage actually pushing current through the armature is $E-E'$. In applying Ohm's Law to this case we have

$$C = \frac{E - E'}{R},$$

C being the current flowing through the armature and R its resistance. If we take the values of E and R given in the example above and assume E' to be 90 volts, we have

$$C = \frac{110 - 90}{0.5} = 40 \text{ amperes.}$$

As is seen from an inspection of Fig. 1, the electromagnet M is magnetized so long as the circuit is closed, because its winding is in the main circuit and the current taken by the motor flows through its winding. When the circuit is broken the field of the electromagnet M dies out and the spring s brings the lever H back to its original position ("full off") to the left.

The type of starting box illustrated above is not the one in common use, and it has been chosen not as a representative type of starting box but simply for the purpose of illustrating the principles, for which purpose it is well suited on account of its simplicity of

construction. The objection to this type of starting box is that if a break should occur in the field circuit the main circuit would remain closed because, as shown in Fig. 1, the coils of the starting box magnet are connected in series with the armature circuit. A break in the field circuit would cause the counter E. M. F. to disappear and this would permit an excessive current to flow through the armature and burn it out. In order to prevent such an occurrence the fuse block *F* is inserted in the main circuit. The fuses in this block are of such capacity as not to permit more than the maximum current, which the motor can safely carry to flow continuously through the motor. If the current should become excessive the fuses will be quickly heated to such a point as to cause them to melt and open the circuit. This method of guarding against armature burn outs is, however, not entirely satisfactory because a careless attendant might, after a fuse has been once blown, insert another fuse in its place whose current carrying capacity is much larger than that of the original fuse. This larger fuse would on the disappearance of the counter E. M. F., permit an excessive current to flow through the armature coils, which would be sufficient to burn out the armature before the fuse would melt. Some time must elapse before the fuse will become heated to the melting point. With a fuse of the proper capacity the time required will generally be too short to allow the current to burn out the armature; but with a fuse whose capacity is greater than it should be, the time required to melt the fuse may be sufficiently long to allow the armature to burn out.

FIG. 4

On account of the objections stated above most starting-box magnets are connected in series with the field circuit. In that case if a break should occur in that portion of the circuit, the starting box magnet will lose its magnetism and the lever will be pulled back by the spring to its "off" position, and thus open the main circuit. Even with this type of starting box a fuse block should be included in the main circuit, because it requires some time, even though that time may be very short, for the magnetic field of the starting box magnet to become sufficiently weak to allow the spring to pull the lever back. If for any reason, therefore, the handle should not come back to its "off" position quick enough, the blowing of the fuse will open the circuit and thus prevent injury to the armature.

Fig. 3 shows a type of starting box manufactured by the Cutler-Hammer

Mfg. Co., known as an *overload starting rheostat*. It derives its name from the fact that it has an attachment for automatically shutting down the motor when the same becomes overloaded. The overload attachment consists of a small magnet whose coils are connected in series with the main circuit, and which, consequently, carry all the current consumed by the motor. When this current becomes excessive the magnet attracts its iron armature and closes a short circuit around the terminals of the retaining magnet which holds the lever in the proper position for running

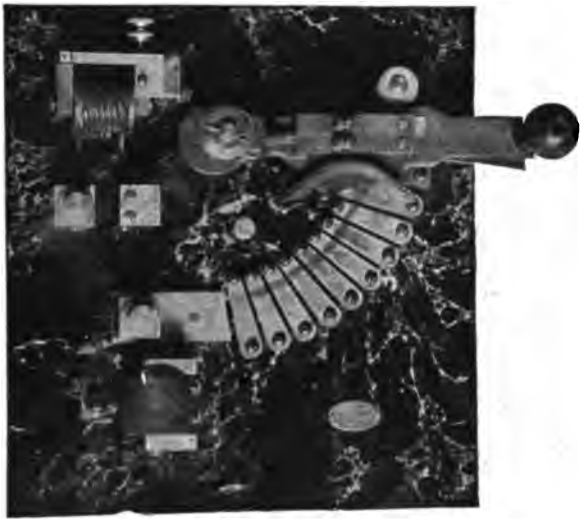

FIG. 5

the motor. This short circuit is closed by means of two little bronze fingers *f f* which scrape against two little brass posts *p p*. The retaining magnet is thus demagnetized and the lever flies back, gradually inserting all the resistance and finally opening the circuit and thus shutting down the motor. Even with this type of starting box, fuses should be used, because too great dependence cannot be placed on the overload attachment to protect a motor from excessive current. The overload attachment is generally connected to act as a safety device for overloads not greater than 50% above the rated capacity of the motor with which it is used. For greater overloads the fuses are depended upon to quickly open the circuit. By using the overload attachment, larger fuses may be used which will save the annoyance and expense of frequent renewal of fuses; because without the attachment the fuses would be required to take care of the least amount of overload; hence a fuse of such size or capacity would have to be used which would blow with a slight excess in current strength beyond that which the motor can safely stand. By using the overload attachment, however, all overloads below 50% will be taken care of by this device, and only currents greater than this will be depended upon to blow the fuse. As this arrangement will considerably reduce the renewal of fuses, much better and more expensive fuses may be used. This is an advantage, because a good fuse will act better when the moment arises at which quick action on its part is necessary, whereas an ordinary fuse under the same condition might act slowly enough to permit a burn out.

Figs. 4 and 5 are illustrations of two styles of overload motor starters, the former suitable for current loads ranging from 4 to 24 amperes, and the latter suitable for loads ranging from 60 to 175 amperes. The frames of these boxes are made of iron. The inner surfaces of these frames are coated with an insulating enamel baked on at a high temperature. This coating prevents the possibility of any portion of the resistance wire in the box forming a ground by coming in

contact with the iron frame. The front of the box on which the contact points, lever, magnet, etc., are mounted, is of slate, and the general appearance of the front is shown in Figs. 4 and 5. The sides of the box are made as nearly open as possible to give good ventilation, so as to permit the heat generated in the coils, from the current passing through them, to be carried away. This is a very important feature which all starting boxes should possess, otherwise they are liable to become very hot and cause trouble.

OUR GIANT INDUSTRY

From an article by Carl Hovey, in Ainslee's Magazine

THERE are in use on the railroads of the United States 37,000 locomotives and 1,500,000 cars. There are invested in the railroads $13,000,000,000, which is a fifth of all the money in the world. They give employment to 1,000,000 men.

The railroad business in the United States has been created in seventy-three years. In 1828 there were in the whole country three miles of track, two locomotives, and no business. In 1899 the railroads of the country earned $140,000,000, and there were 190,000 miles of main track, and, in addition, probably 60,000 miles of double and side track.

Mr. Hovey considers the railways only as they are, with their masterful organizations and their capacity for transportation of freight and passengers. He does not consider investments incidental to the wear and tear of service.

If there are now 37,000 locomotives in use, it is fair to assume that 10 per cent. of these go out of service every year. Here is a call for nearly 4,000 locomotives annually, to say nothing of the increasing demand for heavier engines. If there are 1,500,000 cars in use, it is probable that 100,000 cars are lost every year, the wastage calling for that number of new cars.

In every department of railroading there has been rapid progress and great improvement. The yearly extension in railroad lines does not show in figures now as it did twenty years ago, because we have practically reached our limit in great trunk lines, but in organization, in equipment, in the study of details, and in the minutia of management we are going forward more rapidly than in the era of rapid railway building.

Old rails have given place to new. Old locomotives have been retired in favor of new. Passenger and mail trains are such as were not thought of thirty years ago. Apparently there has been less improvement in freight trains, but here appearances do not count. The improvement is in the closer business management that makes the freight business of the road the money-making department.

Undoubtedly competition has played an important part in developing our railway systems and has contributed greatly to our superior equipment and management. There is more call for good generalship in the railway business than in any other. There has been rivalry in construction as well as in management, and some of the best minds of the century have entered into a struggle for mastery in which success was measured by results most satisfactory to the public. This competition has given us more railways than exist in all Europe, and the best equipment and the best service in the world, and has called for the investment of $13,000,000,000 of private capital.

USEFUL IDEAS

HOW TO MAKE AN ALUMINUM PUSH-BUTTON

J. L. Dickson

Select a good design of a bronze push-button, and procure a small card-board box large enough so that when the push-button is placed therein there will be a distance of about one-half inch from all edges, also from the top of the box to the top of push and from bottom of box to bottom of push.

Now take some Plaster of Paris and mix with water until a good paste is made, then fill both bottom and top of the box with this paste and quickly make impressions by pressing the bronze push-button (well-oiled) down in the paste, then take the opposite side of button and press it down in the other box.

After standing a few seconds, remove the bronze push and allow the impressions to become hard, then place the two together and bore a hole in one side, through which pour melted aluminum, and place the springs and button in the proper positions.

After the above operations have been accomplished, polish the push-button by means of a fine emery-wheel, and you will have a beautiful push-button, which will not rust or tarnish, and is equal to any on the market.

RIVET SPACING

Editor Science and Industry:

DEAR SIR:—In the November number of SCIENCE AND INDUSTRY you published an article entitled "Rivet Spacing in Plate Girders," by Royal A. Polhamus. You will notice the method as there given is for a girder uniformly loaded, and the shear line is shown and treated as a parabolic curve. This is not true for such a condition of loading. The shear line is a straight line from the corner of the diagram to the apex of the curve, i. e.,

$$\sqrt{(\tfrac{1}{2}l)^2 + Pe^2}.$$

Thus the method gives too small a pitch except at the ends, and might prove a source of error to any draftsman who should adopt it in actual practice.

While it is imperative that the number of rivets in a plate girder should be sufficient to transfer the flange stress to the flange angles and cover plates, the aim of practical girder builders is to build a girder that shall fulfil its office of supporting its load, and not primarily to satisfy a formula based on assumptions which have scarcely been verified by actual experiment. The formulas for flexure in a beam under loads, while excellent and reliable as guides, are never used without adopting a factor of safety of at least three, and generally five, and sometimes ten. In the case in question the assumption is made that the web carries all the shear, and the flange angles resist the bending moment. This is a safe rule, but it is not amenable to demonstration. Another assumption is made in the method of loading, which is generally in excess of that which can ever come on the girder. Then, again, the friction, which in power-driven rivets is enormous and which nips the sections riveted, is neglected as being too uncertain a factor to consider. Taking all these conditions into consideration, it would not appear reasonable to rely too firmly on the formula for spacing rivets, especially as that formula gives

results which, under a condition of uniform load, would be entirely too large for the spacing near the center of the girder. Therefore, I would suggest as a safe rule, and one which has worked very well in my own experience, to obtain the pitch at the ends from the maximum end shear, and gradually increase the pitch until near the center, where the spacing should never exceed 6 inches. If the girder is a deck bridge for a railroad, the pitch should not exceed 4 inches, in order to have at least 2 rivets under each tie. If the girder is a through bridge, the pitch should be uniform between the points at which the floor beams are attached.

It frequently happens that a draftsman has to figure the pitch of rivets in a girder where no loads or stresses are given and he has only the sizes of the flanges and webs to guide him. In such a case the following formula may be used. It is obtained simply by substituting in the ordinary formulas for flexure,

Let $L =$ length of girder in feet;
$D =$ effective depth of same in inches;
$A =$ next section of lower flange;
$f =$ allowed flange stress per square inch;
$S =$ end shear for uniform load;
$D_1 =$ vertical distance between rivet lines;
$p =$ pitch of rivets at end of girder;
$r =$ value of one rivet.

Then, $$S = \frac{f A D}{3 L}.$$

If we assume $D_1 = D$ which can be done without much error in most cases,

then, $$p = \frac{3 r L}{f A}.$$

In the absence of specified values for f it would be good practice to use about 10,000, and for the value of the rivet in bearing on the web about 15,000 lb. per square inch.

While I would not, on any account, advocate the adoption of rule-of-thumb methods in designing structural details, still I am tempted to believe that some draftsmen exercise a painful and unnecessary effort in figuring some little details which ordinary experience and judgment should decide at a glance, and a good deal of time and expense saved without impairing the efficiency of the structure.

Respectfully,
A. M. Felgate.

A SIMPLE DEVICE FOR OPENING A FURNACE DAMPER

Mr. E. C. Haskins, of the the American Radiator Co., presents us with a description of the following contrivance, which is especially devised by him for the purpose of automatically opening the draft to a steam boiler, a hot-water heater, or a hot-air furnace.

Many people prefer to dampen their boilers and furnaces during the night, and, of course, it is essential that they

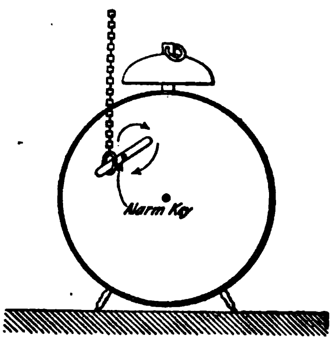

Fig. 1

open the dampers or otherwise adjust the draft early in the morning in order to get up heat. A large amount of coal is saved by this procedure, but the house cools off considerably during the night and it is usually quite cold in

the early morning. This makes it uncomfortable for the family for at least one hour, until the heater has had time to warm the building again. In order to overcome this discomfort Mr. Haskins firmly attaches a common 75-cent

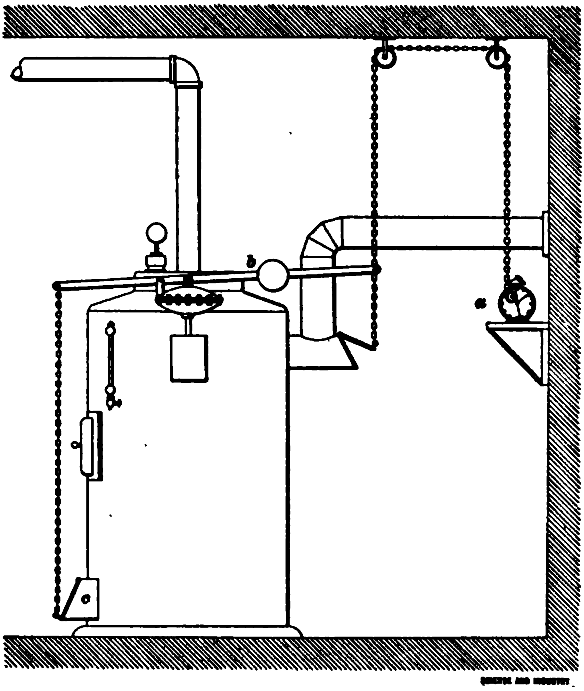

Fig. 2

alarm clock on a shelf in the boiler room, as shown at *a* in the accompanying figure, which shows it connected up complete to a steam heater. A light chain is attached to the weighted end of the damper regulator *b* and passes over pulleys attached to the ceiling. At the other end of the chain is attached a small ring which is connected to the key of the alarm, as shown in Fig. 1. The length of the chain is adjusted so that when the ring is attached to the alarm key, the weight end of the lever *b*, Fig. 2, is raised sufficiently high for the damper *c* to be entirely closed. The air supplied to the heater is thus shut off and the fire is dampened for the night. The clock is set so that the alarm will go off at the desired time. When the alarm is set in motion the ring is thrown from the key, the weighted end of lever *b* falls, and the damper *c* is opened. This allows fresh air to pass through the fire. Then steam is soon raised in the boiler and the house can be warmed before the people are up.

This apparatus does not affect the general working of the dampers at any time when the alarm is run down, because the slack chain will allow for the free movement of the lever. The clock only controls the dampers at night after it is wound up.

NOTES

If an inventor forgets or abandons his invention after a reduction to practice in private, and before a public use, his competitor may claim the patent. If he forgets or abandons it after a public use, his competitor can take no patent, but the forfeiture will inure to the benefit of the public.—Power and Transmission.

At the Long Sault Rapids, near the St. Lawrence River, a canal and water-power plant are to be constructed. It is intended to build a canal 200 feet in length, 50 feet wide at the bottom, and 21 feet deep, to utilize the water. Three turbines of 1,000 horsepower each will be used.—Electrical Review.

EDITORIAL COMMENT

With this number we commence the Seventh Volume of SCIENCE AND INDUSTRY. It has been customary in the past to have twelve numbers in each volume, but in order to have the new volume start with the January number we were obliged to reduce Volume Six to eleven numbers. Hereafter the new volume will always start with the January number and contain twelve numbers so that there will be a complete volume for each calendar year.

With this number we also issue the index for Volume Six. As will be seen, there are really two indexes, one arranged according to the character of the articles and the other, which contains the "Answers to Inquiries," arranged alphabetically. This will, we think, be of considerable convenience to those wishing to look up information on any particular subject. Persons having the eleven numbers of Volume Six can send them to this office and have them bound, together with the index, for one dollar.

The Registrar of Lehigh University reports that the University is erecting a stone laboratory, 90 ft. × 33 ft., to be used in connection with the steam engineering work of the course in Mechanical Engineering, and that next fall they will offer a new and extended course in Electro-Metallurgy—the first of its kind, it is believed, to be established in this country.

The departments of Civil Engineering and of Geology at Lehigh University have recently received valuable gifts in the shape of surveying instruments, microscopes, and geological specimens for the microscopic study of rocks.

In the American Thresherman, J. C. Watt gives some ironical advice to engineers. It is intended, of course, for those who have charge of portable engines, but much of it is appropriate, "by contraries," to the management of steam plants generally. He says:

When your engine is running well, do a little monkeying; keep tightening up; it will give the feeders a rest.

Remove your fusible plug and put in a hard one; a soft plug is annoying when it melts.

Do not try your gauge-cocks; they are only ornaments.

It is a dirty job cleaning flues; let them alone.

Let your cylinder growl; it is music to a good engineer.

Tighten your glands until the rods get hot; it is good for packing manufacturers.

Pour on lots of oil; it looks nice to see it run over the boiler and upon the ground.

Keep your engine pounding so that the neighbors will hear it; it is a good advertisement.

Shut your furnace door tight when you light your fire; it will give you lots of time for gossip.

Do not sweep out your smokebox; let it rust out.

Do not clean your engine when it breaks down; the broken part is much easier to handle.

Do not try your safety valve; you are liable to get to heaven sooner than you expect.

Never blow out your lubricator; it is only a waste of steam.

Do not clean your fire; your engine will steam easier when it is full of clinkers.

Never look at the interior of your

boiler; the more mud the less water you need.

In frosty weather leave the pet-cocks all closed; it costs nothing for repairs.

Never oil your governor with kerosene; when it gets gummed up you will get to your destination all the sooner.

And above all, when your employer is engaged with any one, leave your engine and listen to what is going on; you may be able to transact his business some day.

BOOK NOTICES, CATALOGUES, ETC.

THAT MAINWARING AFFAIR. A novel by A. Maynard Barbour. J. B. Lippincott Company, publishers, Philadelphia. Price $1.50.

MILLIONAIRES AND KINGS OF ENTERPRISE, by James Burnley, published by J. B. Lippincott Company, Philadelphia. Price $6.

THE ELEMENTS OF ALTERNATING CURRENTS, second edition, by W. S. Franklin and R. B. Williamson. The Macmillan Company, New York. Price $2.50. This is the second edition of this work, the first edition being published about two years ago. The whole book has been rewritten and greatly enlarged, about 125 pages having been added. The book now contains 333 pages and 238 illustrations. This book is intended to give a knowledge of the theory and practice of alternating currents such that the student will be able to understand the principles and operation of alternating current apparatus. While mathematics is, of course, necessary, especially in proving the formulas, most of the derivations are printed in smaller type than the body of the book and may be omitted without interfering with the understanding of the subject in hand. Five new chapters have been added on alternating current machinery, giving information as to the apparatus in common use and points relating to its operation. These chapters include transformer connections, synchronizing of alternators, rotary convertors, etc. The book has been carefully printed, and the free use of illustrations and diagrams aids materially in understanding the subject. Each chapter is concluded with a series of practical problems with answers.

COMPRESSED AIR, ITS PRODUCTION, USES, AND APPLICATIONS, by Gardner D. Hiscox, M. E. Published by Norman W. Henly & Co. Price $5.00. It has long been felt by seekers after knowledge that the subject of compressed air has not been given its due share of attention by scientific writers, and so, while it is not the only work on the subject, Mr. Hiscox's treatise is by far the most comprehensive that has yet been issued. Starting out with a short historical sketch of the early uses of compressed air by the ancients, the physical properties and thermodynamics are thoroughly discussed. Air compressors, pneumatic tools, and the uses of compressed air in railway service are then taken up and treated in an admirable manner, while the chapter on liquid air contains much that is interesting. The book concludes with a list of patents issued by the United States Patent Office on compressed air and its appliances from 1875 to July 1, 1901, which is of great value as a reference. The book is bound in cloth or half morocco, well printed on good paper, and the illustrations, which number something over five hundred, are most excellent. Taken altogether, it is a book that we can unhesitatingly recommend as a most valuable addition to any engineer's library.

One of the most popular specialties now on the market is the Merwarth Metallic Gasket, made by the Merwarth Metallic Gasket Co., 107 Liberty St., New York City. These gaskets are used for air, steam, and water, and are reported to have satisfactorily withstood pressures as high as 300 pounds without leakage. They are largely used for column pipes in mines and are made large enough for large steam-chest covers. Among the good features claimed for them are that they do not deteriorate in stock, and being furnished ready for use there is no waste from cutting.

Among the thriving concerns of the Middle West, that of Geo. W. Hoffman, Indianapolis, Ind., manufacturer of U. S. Metal Polish, and several other specialties, ranks well to the front. Mr. Hoffman now has branch stores established in Chicago, New York, and San Francisco, and reports lively business from all quarters.

ANSWERS TO INQUIRIES

NOTE.—Address all letters containing questions to be answered in this department to Editor SCIENCE AND INDUSTRY, *Scranton, Pa.*

1. Put this address both on the envelope and at the head of the letter.

2. Only questions of general interest to our readers will be answered.

3. No questions will be answered by mail.

4. Drawings or sketches accompanying questions should be made on a separate sheet of paper, and should be drawn as clearly as possible.

5. The names and addresses of the writers must accompany the letters, or no attention will be paid to them. Unless otherwise requested, we will publish only the initials and address of the writer.

6. Reference to inquiries previously answered should give date of issue and number of question.

7. Questions cannot be answered in the issue of the month immediately following their receipt.

8. Any book not out of print and for sale by regular dealers may be ordered through the magazine.

9. We will not undertake to calculate windings of dynamos and motors, as this involves considerable work and is seldom justified.

MECHANICAL

(1) What size rope should be used for hauling a load up an inclined plane dipping 1 ft. in 20? The weight of the load is 40 tons and the drum on which the rope winds is 5 ft. in diameter. What size rope would have to be used if the diameter of the drum were 10 ft., other conditions remaining the same?

P. C., Cape Breton, Canada.

ANS.—According to data published in the Coal and Metal Miners' Pocketbook, the pull on the rope, upon an incline of 1 ft. in 20 ft. is 140 lb. per ton. This includes the pull due to the rolling friction and the inclination of the plane, but not the weight of the rope. The pull for a load of 40 tons would therefore be $140 \times 40 = 5,600$ lb., or 2.8 tons. A steel, hemp center rope, composed of 6 strands, 7 wires to the strand, is ordinarily used for this service. By turning to the table of safe strengths of steel ropes of this class in the above mentioned handbook, we find that a $\frac{11}{16}''$ rope will safely draw 3.16 tons. If the rope is comparatively short, this diameter should give satisfactory results. If, however, the rope is quite long, a $\frac{3}{4}''$ rope would be preferable, and if it should be excessively long, a $\frac{7}{8}''$ rope should be used. The minimum size of drum for a $\frac{3}{4}''$ rope is $4\frac{1}{2}$ ft. and for a $\frac{7}{8}''$ rope 5 ft. A 5 ft. drum could therefore be used, but a larger diameter is ordinarily preferable. If the drum were made 10 ft. in diameter, the diameter of the rope would be the same, but the wear would be less, and the life of the rope increased.

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(2) (*a*) How do you determine the mean effective pressure in pounds per square inch of a steam engine, and how do you use it to determine the horsepower of the engine? (*b*) In the formula for finding the horsepower of an engine, why do you use the constant 33,000? (*c*) How far will a No. 7 Cameron air pump draw water with a pressure of about 50 lb., and what is the longest distance any pump will draw water? (*d*) I have seen the following formula for determining the number of feet of belting in a roll: "Take the sum of the inside and outside diameters and multiply by the number of turns and by the decimal .1309." I have tried this but it did not give the correct result. Is the rule correct?

G. A. P., Republic, Mich.

ANS.—(*a*) The mean effective pressure (or M. E. P. as it is usually expressed) is found by taking an indicator card and multiplying the average height of the diagram by the scale of the spring used. (*b*) In the formula $\frac{Plan}{33,000}$, P = the M. E. P. in lb. per square inch., l = length of the stroke in feet, a = area of the piston in square inches, n = number of single strokes per minute. The constant 33,000 is used because 33,000 ft.-lb. of work per minute is taken as the equivalent of 1 horsepower. (*c*) Any good pump, drawing clear cold water through an amply large suction pipe with no bends in it, and which is perfectly air tight, ought to draw the water 25 feet. (*d*) The rule is approximately correct. Be sure to take the diameters in inches. This gives the length of the belt in feet.

***

(3) Please tell me how to clean the cylinder of oil which has become dried on the cylinder of a Corliss engine? The cylinder is hot all the time. I have tried soap and water, and also strong lye, but this takes the enamel off. The oil has dried only on the nickel parts.

C. S. S.., Canton, N. Y.

ANS.—Try a solution of oxalic acid.

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(4) (*a*) A freight train weighing 1,200 tons is being hauled at a speed of 15 miles per hour. Assuming a resistance of 13 pounds per ton, what horsepower is the engine exerting at the drawbar? (*b*) The power

thus expended in pulling the train is 60 per cent. of the I. H. P.; how do you determine this latter? B. C. E., Philadelphia, Pa.

ANS.—(*a*) The total resistance to traction of the whole train (behind the drawbar) is $(13 \times 1{,}200)$ pounds. The distance traversed in one minute is $\frac{15 \times 5{,}280}{60} = 1{,}320$ feet. The number of foot-pounds of work performed in one minute, divided by 33,000, gives us the horsepower. Or,

$$\frac{13 \times 1{,}200 \times 15 \times 5{,}280}{60 \times 33{,}000} = 624 \text{ H. P.}$$

(*b*) If this is 60 per cent., or $\frac{6}{10}$, of the I.H.P., the latter is $\frac{10}{6} \times 624 = 1{,}040$. In other words, only six-tenths of the power developed in the cylinders passes the drawbar, i. e., is utilized in hauling the train. The expression I. H. P. stands for "indicated horsepower," and refers to the power as determined by the instrument called an "indicator." This power by no means represents the actual amount of steam going into the cylinders, as it takes no account of the radiation and condensation losses. To compute the I. H. P. we first calculate the area of the indicator diagram and then divide by the length, thus obtaining the mean height; this height, multiplied by the scale of the spring used in that particular case, gives us the mean effective pressure (the M. E. P.) on the pistons in pounds per square inch. The spring generally used is a 60 or an 80; this means that every inch height of the diagram represents 60 or 80 lb. steam pressure, as the case may be. Multiply the M. E. P. by the area of one piston, and by the number of revolutions per minute, and by the length of stroke in feet, and then divide the joint product by 8,250. The result is the I. H. P. (In working out an actual case, you would first cancel any common factors, of course.) From the area of the piston should first be deducted half the sectional area of the piston rod, or the whole area if a tail rod is used.

***

(5) Please tell me how to compute the power required to operate a machine. I wish to estimate how many horsepower it would take to run several printing presses, etc., that have heretofore been run by hand and foot power. C. D. C., Pacific, Mo.

ANS.—There is no general rule by which the power required to operate a machine can be computed with any degree of accuracy. A person having a wide experience with a certain line of machinery can generally estimate pretty closely how much power will be required for a certain machine, but a person without that experience is likely to come wide of the mark in making the estimate. For this reason we would advise you to apply to the makers of your presses. Theoretically, the finding of the horsepower is a very simple matter, being merely the division of the foot-pounds of work done per minute by 33,000. The trouble arises in determining the amount of work done per minute. In some cases this can be accurately determined by a dynamometer, which will give it quite accurately, but obviously involves beforehand that the machine is already at work and that there is an ample supply of power. With the aid of the dynamometer it can then be determined how much power is actually used. For a description of this instrument we would refer you to "Dynamometers and the Measurement of Power," by Flather, which you can obtain from the Technical Supply Co., Scranton, Pa. Price $2.00.

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(6) (*a*) Please explain what a rust joint is. (*b*) What is meant by the dead end of a pipe when the vent is a distance from the end, and why is it so called?
F. A. S., San Francisco, Cal.

ANS.—(*a*) A rust joint is made by means of a rust cement, which, as the name implies, makes the joint tight by rusting in place, and filling the space with iron rust. There are several formulas for the cement, all of which have given good service. The following is one of the simplest and best of these: Mix 2 ounces of sal amoniac with 5 lb. of cast-iron borings, and make into a thick paste by adding water. The mixture must be used as soon as prepared. By using only one ounce of sal ammoniac the cement will set slower, but will be stronger. The joint is made by ramming the cement into the open space, and allowing it to stand until the rust is formed, and the cement thoroughly set. It is used to cement joints in pipes and fill holes or cracks in iron. It is inexpensive and very serviceable for rough work. This mixture is also sometimes used in setting engines or other machines upon their foundations. (*b*) The dead end of a pipe is the closed end beyond the vent, in which the air is trapped. For instance, if in a vertical pipe, which is closed at the upper end, a vent be placed some distance from the top, the water cannot rise above the vent, since the air above that point cannot escape. This part is called the dead end.

***

(7) From the sketch of the boiler rooms as shown here, give best method of piping for two Hancock Inspirators. They are to be flat against the wall and as close together as possible.
A. D. S., Flint, Mich.

ANS.—The method of piping to be adopted depends entirely upon the requirements and the relative position of the

injectors in reference to their point of delivery and supply, but as neither the requirements nor any other needed information is given on your sketch, we can only give a general answer. We presume you wish to install two inspirators, each of which has sufficient capacity to supply the four boilers at once, so that one inspirator is held in reserve. In that case the best modern practice would be to supply each inspirator with its own set of piping so arranged as to be entirely independent of each other. The steam pipe for each inspirator should be connected directly to the boiler instead of to a main steam pipe, and should be high enough up to insure dry steam. The suction and delivery pipes should be as short and direct as possible, and of ample size. Each branch delivery pipe should have its own check-valve and globe valve. If the conditions of service are such that at times only part of the boiler plant is running, the steam piping for the inspirators should be so arranged that steam can be taken at will from any boiler in the plant.

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(8) (*a*) Please give me a formula of a liquid in which to dip cast brass so it will come out bright and retain its color when exposed to weather without tarnishing. Is there any way to do this without using lacquer? (*b*) Give me the best method of annealing small cast iron castings which have become chilled. Does this process require a special furnace.

C. M. G., Valleyfield, P. Q., Canada.

ANS.—(*a*) Try a solution of two parts of water, two of sulphuric acid, and one of nitric acid mixed as follows: First mix the water and sulphuric acid and let these cool and then add the nitric acid; when this solution is cool it will be ready for use. Dip the castings which are to be cleaned in this solution and withdraw them quickly; repeat this operation until the castings are bright; rinse in cold water, then in hot water, and then lay them in sawdust to dry. (*b*) The best method we know of is to pack the articles in an airtight iron box in pulverized charcoal and to heat them in any convenient furnace, keeping the box and its contents at a red heat for from six to eight hours, and then allowing them to cool very slowly. This method will generally anneal the castings quite satisfactorily.

***

(9) Is it a fact that a projectile gains velocity after leaving the mouth of the gun? That is, has it more penetrating power at 10 feet than at 2 feet from the muzzle?

L. W. G., Buffalo, N. Y.

ANS.—We believe that recent experiments have demonstrated that the velocity of a rifle bullet reaches its maximum at a point about 10 feet from the muzzle.

(10) Please tell me where the Grant-Ferris gasolene engine is made.

F. H., Slatington, Pa.

ANS.—We are not familiar with this type of engine. Perhaps some of our readers can furnish the information.

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(11) If an engine is stopped so that the crankpin is on the center at the top of stroke and the rod is disconnected and the pin turned round so it is on center at the bottom of the stroke, will the rod then be in the right place to connect, or will it have to be moved forward or back?

F. E. P., Bucyrus, Ohio.

ANS.—The position of the rod will not have to be changed?

ELECTRICAL.

(12) (*a*) Please work out the formula for finding the efficiency of the electric plant described below. There are two 750 K. W., 10,500 volt generators, each direct-connected to a separate turbine of 1,400 H. P. under 110-foot head at a pressure of 40 lb. per square inch. This is for full load, $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$ load. (*b*) In a three-phase alternator suppose the load shown on an ammeter is, say, 2 amperes on one leg, 4 on another, and 5 on another. The voltage is 10,700. How would you proceed to find the true output in K. W.? Would you not add the readings on the three legs together, divide by 3 to obtain an average, multiply by the root 1.78, and multiply by the voltage? Would adding all the readings on the three legs together, without finding the average and proceedings as given above, produce the true output, and if not, why? (*c*) What is the formula for finding the flow of a river in feet per minute?

J. C., Sturgeon Falls, Ont.

ANS.—(*a*) There is no formula that can be given for determining the efficiency of an electric light plant. The only way to get at it is to determine the power delivered to the wheels by measuring the flow of water and the head. At the same time readings are taken of the power delivered from the switchboard. The ratio of the total power delivered from the switchboard to the total power delivered to the wheels represents the plant efficiency, and takes into account all losses in the wheels, dynamos, and driving gear. (*b*) Since the voltage, 10,700, is high, we presume that the armature is Y connected. The pressure generated in each phase will therefore be $\frac{10,700}{\sqrt{3}}$. The power generated in phase 1 will

be, $\frac{10,700}{\sqrt{3}} \times 2$; in phase 2, $\frac{10,700}{\sqrt{3}} \times 4$; and in phase 3, $\frac{10,700}{\sqrt{3}} \times 5$. This assumes that the current and E. M. F. in the individual phases are in phase with each other. The current in each phase is the same as the current in the corresponding line. The total power is the sum of the powers delivered by the separate phases or $\frac{10,700}{\sqrt{3}}(2+4+6) =$ 74,134 watts. (*c*) See the Home Study Magazine for May, 1897, which contains a complete article on this subject. It can be had by remitting 10 cents to this office.

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(13) I wish to get a book which will give me some practical information in regard to telegraphy.

G. A. H., Chicago, Ill.

ANS.—We should advise you to procure a book entitled "The Telegraph Instructor," by G. M. Dodge, price $1.00. This can be be secured from the Technical Supply Co., Scranton, Pa.

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(14) (*a*) Can a 16-candlepower incandescent lamp be operated by dry or wet battery, and if so, which is the best kind to use? (*b*) How many batteries will it take to operate one lamp? (*c*) To operate more than one lamp, how would you wire them? (*d*) What will be the voltage and current required to operate one or more lamps? (*e*) If the batteries can be used for this purpose, will it be better to use one large one or a number of small ones?

F. E. P., Bucyrus, Ohio.

ANS.—(*a*) Yes, but it is an expensive and troublesome way to provide current for this purpose. Wet batteries last longer than dry, and can deliver more current because their internal resistance is lower. (*b*) It would require at least fifty cells to operate a 16 C. P. lamp for any considerable length of time without running down. (*c*) This would depend to some extent on the number of cells available. The lamps would most likely be connected in parallel, and an additional group of cells would be added in parallel for each additional lamp operated. (*d*) If you connect the lamps in parallel, as is generally the case, the addition of each lamp calls for a corresponding increase in current, but the voltage does not have to be increased. For example, if you had an arrangement of cells giving 50 volts and 1 ampere to operate a single 16 C. P. lamp, the addition of another similar lamp in parallel would call for a total current of 2 amperes at 50 volts. If lamps are connected in series, the applied E. M. F. must be increased in direct proportion but the current remains the same. Thus, if two, 50-volt lamps requiring 1 ampere were operated in series, the voltage applied would be 100 volts, and the current through both lamps would be 1 ampere or the same as the current required for one lamp. (*e*) It would be necessary to use a number of cells, because a single cell would not give more than 1 or 2 volts, and it is not possible to obtain efficient 16 C. P. lamps for such a low voltage as this.

***

(15) (*a*) How many watts equal 1 kilowatt? (*b*) In the accompanying sketch the line carries 125 volts. Could a bell that is wound with No. 28 copper wire be connected between the terminals in series with a 4-candlepower incandescent lamp to reduce the voltage so that when the button if pushed, thus closing the circuit, the lamp will light and the bell ring, or would the current be too heavy for the bell and burn it out? (*c*) How can I recharge dry batteries? (*d*) Which is the positive pole of the Wagner dynamo? (*e*) How far will a rotary pump draw water by suction? (*f*) What is the proper speed to run a rotary pump 10 inches in diameter to force water to a height of 40 feet?

L. M. C., Spokane, Wash.

ANS—(*a*) One thousand. (*b*) The coil would stand the current all right as it does not flow through the coil for long at a time. (*c*) Dry batteries may be recharged by connecting them to an ordinary 110-volt direct-current lighting circuit. A lamp should be connected in series to limit the current, and the positive line should be connected to the carbon terminal of the battery. Recharging dry batteries is not a very satisfactory operation. These cells are so cheap that the best way in the end is to throw them away and buy new ones. (*d*) It all depends on how the dynamo is connected. Either pole may be positive. In the case of an alternator, neither pole can be called positive, because the polarity alternates rapidly. The most convenient way to test the polarity of a direct-current machine is by means of a Weston voltmeter, but if one of these is not at hand, connect one terminal of a lamp to one terminal of the machine and the other to a piece of wire. Connect a second piece of wire to the other dynamo terminal and dip the two ends in acidulated water. The end from which the smaller number of bubbles is given off is connected to the positive pole. The lamp is connected in circuit merely to prevent short-circuiting. (*e*) The most efficient total lift for the centrifugal pump is approximately 17 ft. (*f*) This depends somewhat on circumstances; it would probably be necessary to run about 600 r. p. m.

(16) Please show by a diagram an arrangement by which a telephone and telegraph can be operated on a metallic circuit line with open circuit batteries, so that they can be thrown in or out at will and the batteries be in circuit only when used for telephoning and telegraphing.

T. A. S. Columbus, Ohio.

ANS.—We are unable to tell from above question whether you desire to telegraph and telephone simultaneously, or merely to use the same batteries for telegraphing at one time and telephoning at another time. Fig. 1 shows one way of telegraphing and telephoning simultaneously over the same pair of line wires. The other end must, of course, be connected in the same way as shown here. This is the Morse open-circuit telegraph system, in which the telegraph battery is on closed circuit only when the telegraph key is pressed down. This system is used across the Atlantic, but never in the United States, Canada, or Mexico. Two simultaneous telephone and telegraph systems used in this country, in which the Morse closed-circuit telegraph system is used, you will find fully illustrated and described in the July, 1900, and April, 1901, numbers of SCIENCE AND INDUSTRY. These numbers you can get for ten cents apiece. Fig. 2 shows you a method in which an open-circuit battery B_1 is connected so that it may be used for the telephone transmitter or for telegraphing. Usually this would not be practical, because a much stronger battery is necessary for telegraphing than for the telephone transmitter. Another battery is, of course, necessary in each case for the sounder, but in Fig. 1, although not so shown, the same battery could be used for both the sounder and transmitter.

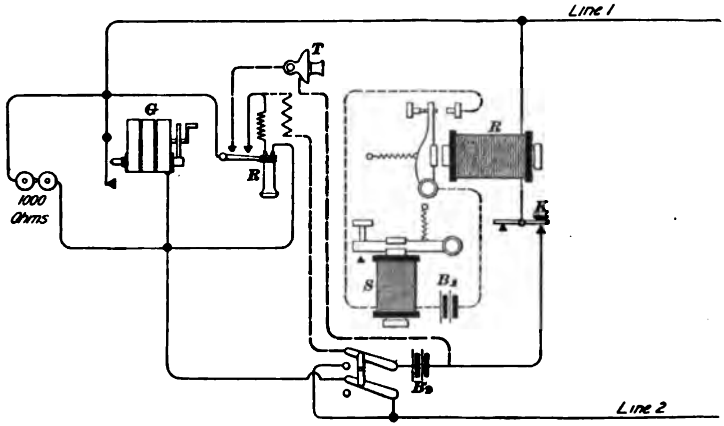

FIG. 1

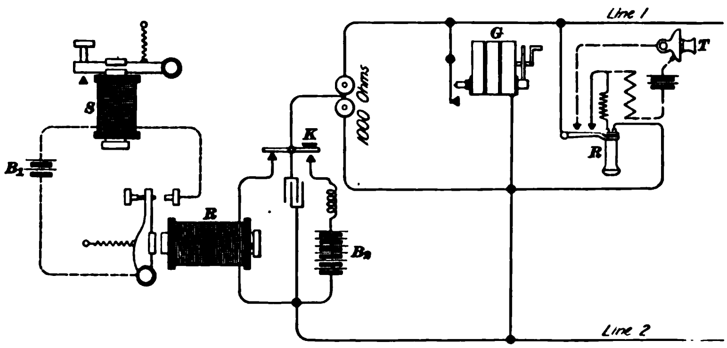

FIG. 2

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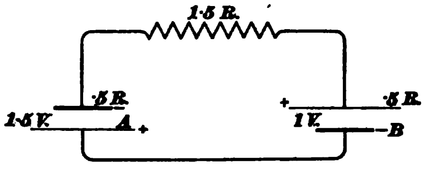
(17) (a) How does the Carré electric machine operate? (b) Has any method of cleaning oil wells by an electric heater been successfully employed? (c) Shingo & Brooker's "Electrical Engineering," page 95, states in effect that if two cells, one stronger than the other, be joined in series so that the current from the stronger cell passes through the weaker, the E. M. F. of the latter will be *lowered*. Why is this? Also, if joined in opposition the E. M. F. of the

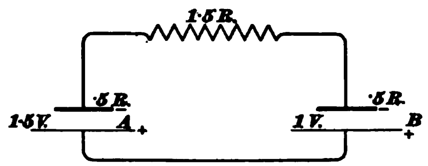
weaker cell will be *increased*. Why so?

P. D., Washington, D. C.

Ans—(*a*) The Carré electric machine belongs to the class of static machines that



(*a*)



(*b*)

operate on the induction principle. In these machines, a small initial charge is provided; this induces other charges which are carried around by the revolving part in such a way as to increase the initial charge. In this way a charge of very high potential is built up and a discharge produced. Other machines of this class are the Holtz, Wimhurst, and Toepler-Holtz machines. A complete description of their action would take up much more space than we can spare in these columns, but you will find a good description in "Thomson's Elementary Lessons in Electricity and Magnetism," which you can obtain in almost any public library. (*b*) We have not seen any description of the use of electric heaters for this purpose. (*c*) This point will be best illustrated by working out an example. *A* and *B* represent two cells, the E. M. F. of *A* being 1.5 volts, and that of *B* 1 volt on open circuit. In each case we will assume that the internal resistance of each cell is .5 ohm and the resistance of external circuit 1.5 ohms. In (*a*) the cells are in series aiding each other, in (*b*) they are in parallel or in opposition. In (*a*) the current will be $C = \frac{\text{Total E. M. F.}}{\text{Total Resistance}} = \frac{1.5+1}{.5+.5+1.5} = 1$ ampere. When a current is flowing there will be a drop in potential in each cell, due to the internal resistance of the cell, and this drop will be $C \times R = 1 \times .5 = .5$ volt. Hence, the E. M. F. across *A* will drop to 1 volt and that across *B* to .5 volt, or in other words, the E. M. F. across both cells decreases. In the second case, the current is smaller because the total effective voltage is only $1.5 - 1 = .5$ volt. The current is therefore $\frac{.5}{2.5} = .2$ ampere, because the total resistance is the same as before. The E. M. F. across cell *B* must now be that across *A* less the drop in the external circuit between *A* and *B*. The E. M. F. across *A* will now be $1.5 - (.2 \times .5) = 1.4$ volts because the drop due to *A*'s internal resistance is only .1 volt. The drop in the external part is $1.5 \times .2 = .3$ volt, hence the E. M. F. across *B* must be $1.4 - .3 = 1.1$ volts which is the open circuit voltage of *B plus* the internal drop in *B*. In other words, when the cells are in opposition and a current is being forced through *B*, the E. M. F. across its terminals must be equal to the counter E. M. F. of the cell *plus* the E. M. F. required to overcome the resistance of the cell, just as in the case of a direct-current motor when the applied E. M. F. is always equal to the counter E. M. F. of the motor plus the E. M. F. required to overcome the resistance of the armature.

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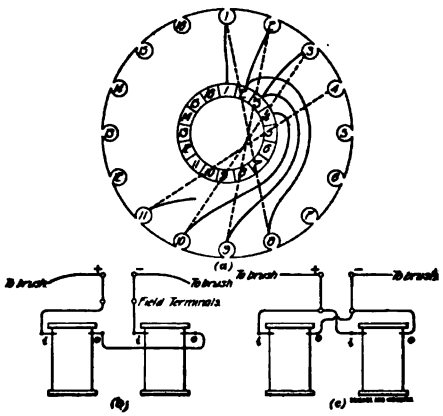
(18) (*a*) How is the armature wound and connected in the figure shown in the article "Sparking Dynamos for Gas Engines," in the July number of Science and Industry? (*b*) Please show by sketch how the fields are wound.

F. G. S., South Lake Linden, Mich.

Ans.—(*a*) The accompanying sketch *a* indicates, diagrammatically, the method of winding. The armature has 16 slots and there are 16 bars on the commutator, hence, there must be 16 coils and 16 pairs of coil terminals. Take the 14-volt winding where each coil consists of 16 turns of No. 20 wire. Since there are but 16 slots to accommodate 16 coils of 16 turns each, it follows that each slot must contain 32 wires. Leave a piece



of wire 4 or 5 inches long for a terminal and wind down slot *1* across the back to *8*, up *8*, and back across the front to *1* again. Continue in this way until 16

turns have been applied, and bring the end back to the starting point and tie it to the beginning of the coil Mark the end in some way to distinguish it from the beginning. Slots *1* and *8* will now be about half filled with wire. Proceed with the second coil, winding it in slots *2* and *9* and tie the terminals together as before after 16 turns have been wound on. The third coil goes in *3* and *10* and so on. After coils *7–14* have been wound on, slots *1* to *14* will be half full and slots *15* and *16* will be empty. Then wind from *8* to *15*, filling the top half of slot *8* and the bottom half of *15*, and so on, until the whole 16 coils have been applied. There will then be a pair of terminals coming out at each slot. The beginning of coil *1* is connected to commutator bar *1* directly in front of the slot, and the end of the coil is connected to bar *2*, the beginning of coil *2* connects to bar *2*, and the end of coil *2* to bar *3*, and so on. The armature could also be wound by winding from slot *1* to slot *9*, instead of *8*, but the chord winding avoids the shaft better. Insulation should be placed between the top and bottom groups of conductors in the slots. (*b*) For the 14-volt winding, the fields are connected in parallel. For the 32-volt winding, they are connected in series. In either case the current must flow around both coils in the same direction when they are viewed from the same end, because the poles are consequent and are formed by two opposing magnetic fluxes. Assuming that the coils are wound in the same direction, and that the inside and outside ends are located at *i* and *o*, sketch (*b*) shows the series connection and sketch (*c*) the parallel. Of course the actual connections used might differ from these, depending on where the coil terminals are brought out.

MISCELLANEOUS

(19) (*a*) How can I solder sheet aluminum? (*b*) Can you tell me how to vulcanize rubber and what action takes place during the process?

S. F. O., Oakland, Cal.

ANS.—(*a*) Aluminum may be soldered by means of a solder composed of 20 parts of aluminum and 80 parts of zinc. The aluminum is first melted, the zinc added gradually, finally some fat is added, and the whole is stirred with an iron rod and poured into molds; for flux use copaiba balsam, 3 parts; Venice turpentine. 1 part, and a few drops of lemon juice. Dip the soldering iron into the same flux. (*b*) The crude rubber as brought into commerce, is quite impure from accidental causes, and, in many cases, from intentional adulteration; it, therefore, must undergo a thorough mechanical cleaning before being submitted to any chemical treatment. For this purpose it is first boiled with water until thoroughly softened, then cut into slices and passed repeatedly between grooved rollers, known as washing rollers, while a stream of cold water flows over it. This crushes and carries away any solid impurities, as well as those which are soluble. Under this treatment Para rubber loses from 12 to 15 per cent. of its weight; the African variety 25 to 33 per cent. After this washing the rubber is carefully dried; neglect of this frequently causes the wares, when subsequently vulcanized, to appear spongy. The caoutchouc is now to be worked over and agglomerated thoroughly, which is done either by passing it repeatedly between rollers heated to 70° to 80° C, or by the aid of a so-called masticating machine. The rubber has now to be mixed with a sulphur needed for its vulcanization and with whatever coloring or weighing matters are to be used. This mixing is effected by the aid of horizontal rollers heated internally with steam, and so geared as to move in contrary directions at an unequal speed. This mixed rubber so obtained can readily be softened by heat, and can now be shaped, molded or rolled into any desired shape, and then submitted to the heat necessary for vulcanization. The vulcanization of rubber consists in effecting a combination of the caoutchouc with sulphur or sulphides, whereby the behavior of the caoutchouc towards heat and towards solvents is changed. Its value for technical purposes is greatly increased by this change. Two methods of vulcanization are to be noted, first, the vulcanizing by mixing with sulphur or metallic sulphides and heating to 125° to 140° C; second, the cold vulcanization process of Parkes, consisting of immersing the rubber article into a solution of chloride of sulphur, in carbondisulphide or benzene. The latter process is only used for small articles, or those consisting of thin layers of caoutchouc, as the action of the chloride of sulphur, even in the 2½% solution usually employed, is very rapid, while at the same time it is superficial, so that it is difficult to control the action properly. In vulcanizing by the first process, that of "burning," as it is termed, the crude caoutchouc is mixed with a varying amount of sulphur—for soft rubber goods, with about 10%, for the hard rubber, or vulcanite, with 30 to 35% of sulphur. Instead of sulphur, metallic sulphides are used, such as alkaline sulphides, sulphide of lead and sulphide of antimony. For red rubber goods the latter is always used; for soft rubber articles the proper temperature for vulcanization lies between 120° and 136° C, for hard rubber from 140° to 142° C. In vulcanizing, only a part of the sulphur is chemically combined, a part remaining mechanically mixed. This can

be largely removed by boiling the finished articles in a solution of caustic soda. Both the air bath and steam bath are in use for heating; the latter, at present, in the majority of cases. This latter heating, which effects the change in the rubber, is frequently called the "curing" of the rubber. In the manufacture of hard rubber articles, the East Indian, and especially the Java and Borneo caoutchouc is used, Para rubber being too expensive, besides being not so well adapted. While in the manufacture of soft rubber the burning or curing was the last process following the shaping of the articles, in the manufacture of hard rubber the curing is generally done before the article is finally shaped. Gutta percha, balata and colophony resin are often added to modify the hardness and elasticity, while a large number of mineral substances, such as chalk, gypsum, zinc, oxide, asphalt, etc , are added chiefly for cheapening purposes

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(20) Will you please give me the practice of surveyors in allowing for the diurnal variation of the compass needle on the vernier? I notice some days the needle will vary nearly a quarter of a degree between morning and noon of the same day and other days; if the weather is cool and cloudy, not nearly so much. Is there any rule for determining the amount for each month throughout the year, and at any time of the day? J. B , Danville, Ill.

Ans.—We think the general practice is to neglect the diurnal variations of the needle entirely. There is no rule for determining the amount of this variation, but the values given in the following table, which are from Johnson's "Theory and Practice of Surveying," probably represent average values of this variation for latitudes between about 35° and 45° north, and may be applied as corrections for the diurnal variation. These values are correct to the nearest minute for Philadelphia, where the observations were made, and are close enough for the purpose. Since the diurnal variation is probably due to the influence of the sun, it is greater in summer than in winter, as shown by this table, and is probably greater on sunny than on cloudy days. The corrections as indicated in the table, are to be added to, or subtracted from, the observed bearings in order to reduce them to the daily mean, that is, to their mean values for the day. The values of the variations given for each month are also to be used for the month preceding and the month following.

Corrections to Reduce Observed Bearings to the Daily Mean.

Month	Add to N E and S W Bearings. Subtract from N W and SE Bearings					Add to N W and S E bearings. Subtract from N E and S W Bearings							
	6 A.M.	7 A.M.	8 A.M.	9 A.M.	10 A.M.	11 A.M.	12 M.	1 P.M.	2 P.M.	3 P.M.	4 P.M.	5 P.M.	6 P.M.
January	1′	1′	2′	2′	1′	0′	2′	3′	3′	2′	1′	1′	0′
April	3	4	4	3	1	1	4	5	5	4	3	2	1
July	4	5	5	4	1	1	4	5	5	4	3	2	1
October	1	2	2	2	1	1	3	3	3	2	1	0	0

***

(21) Is there any convenient method by which the position of the decimal point may be readily ascertained by inspection of the factors in a problem like the following:

$$\frac{398.3 \times 2.07 \times \sqrt{27.3}}{\sqrt[3]{\dfrac{\sqrt{4.893}}{\sqrt{.187}}} \times 3.6749 \times .975}$$

This, of course, is easily calculated with a slide rule, if one knows where to put the decimal point when the work has been done.

R. J. G., C. B., Canada.

Ans.—The place of the decimal point is easily determined by a rough arithmetical approximation. The value of the fraction can be approximated as follows:

$$\frac{400 \times 2 \times 5}{1.6 \times 4 \times 1} = 625.$$

Since the approximate value of the fraction is 625, the whole number part of the true value of the fraction will consist of three figures.

***

(22) (*a*) Please inform me where I can purchase compressed oxygen and ozone used for sterilizing purposes. (*b*) Are there any books giving information on the preparation of oxygen and ozone?

W. G., Huntley, Ill.

Ans.—(*a*) Compressed oxygen, and probably ozone, may be purchased from Underwood & Co., New York. (*b*) The preparation of oxygen and ozone is described in any book on inorganic chemistry. We would recommend you "Inorganic Chemistry," by Ira Remsen, American Science Course—Advanced Series. This book may be obtained through the Technical Supply Co., Scranton, Pa.

(23) How can I obtain the shape of the slats for the louvre windows shown in the accompanying sketch?

H. C. L., Stanwick, N. J.

ANS.—The semicircular window frame may be considered as a half cylinder, and the louvres as oblique planes passing through it. In Fig. 1, *A* shows the elevation of the half cylinder; *B*, a section on the line *k l*; *C*, a side elevation in which *s o* represents the slant of the louvre; and *D*, a development of the section on the line *s o* in *C*. This development is obtained as follows: Divide the semicircle *t k u*, in *A*, into any number of equal parts, as *t 1*, *12*, *23*, etc., and from these points drop perpendiculars to the line *t u*. Since the figure is symmetrical with respect to the axes *k l*, we will consider only the right half in making the projections to *C*. The next step is to project the points *k*, *4*, *5*, *6*, *v*, in *A*, to the line *s o* in *C*; *s o* will then be the true length of *k o'* in the oblique section, and *s 7*, *s 8*, *s 9* will be the true distances for *4' 4*, *5' 5*, *6' 6*. In *D* we lay off *t' u'* equal to *t u* in *A*, and project the points *1*, *2*, *3*, etc. to this line; these perpendiculars will then be the lines on which to measure off the true distances obtained in *C*. Lay off *s' o* equal to *s o* in *C*, and *s' 7*, *s' 8*, *s' 9*, on the perpendiculars at each side of the center line equal to *s 7*, *s 8*, and *s 9*, respectively, in *C*. A curved line drawn through the points *t' 9 8 7 o 7 8 9 u'* gives the shape of the oblique section through the half cylinder. We will now consider the louvre *a b c d* in *B*. To obtain the shape of *a b c d*, we project the points *a* and *c* to *m* and *n* on the line *s o* in *C*, giving the distances *o m* and *o n* which are laid off from *o* on *o s*, in *D*; *a o b* will then be the shape of the upper surface of the louvre, and *c o d*, the shape of the under side. The distances *a b* and *c d*, representing the surfaces of the louvre, might have been taken directly from *B* without projecting in this case, but in obtaining the development of the other louvres it would be necessary to project, and consequently the projections were made to preserve a uniform method. To develop *e f g h*, we project these points to *q v r p* on *s o*, in *C*; then lay off the distances *o v*, *o p*, *o q*, and *o r* on *o s'* in *D* and draw lines parallel to *t' u'* through the points *v*, *p*, *q*, and *r*.

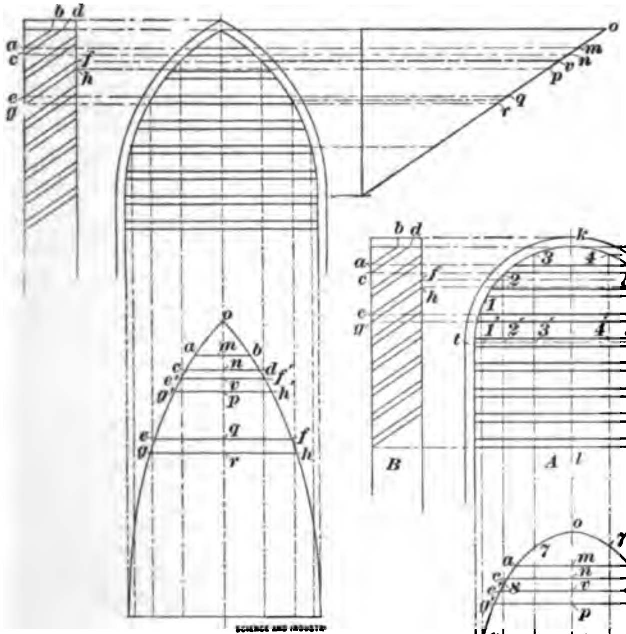

FIG. 2

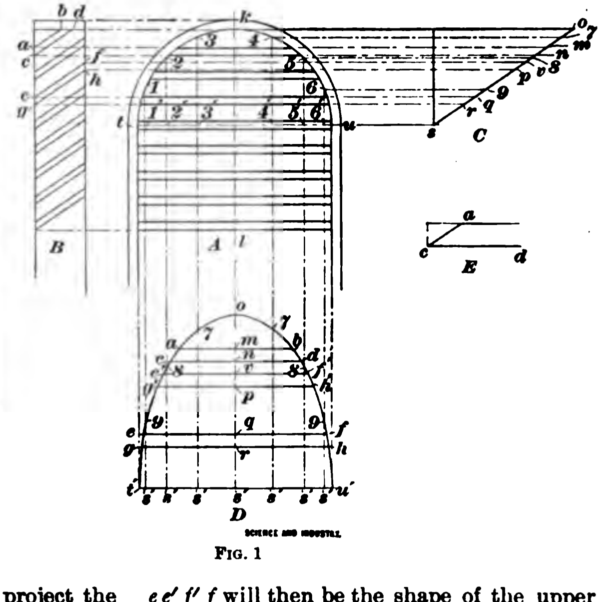

FIG. 1

e e' f' f will then be the shape of the upper surface and *g g' h' h* of the lower surface of the louvre *e f g h*. The other louvres should be developed in the same manner. In laying out the work, the board from which the louvre is to be cut should be beveled off on one edge to correspond with the angle *a c d* in *B*, as shown at *E*. The center lines should then be drawn, and the development of the surfaces of the louvre laid off on the upper and lower sides of the board. The ends of the board should be beveled off to conform to the curve *b d*

in *D*. The louvres for the pointed window frame are developed in the same manner as described above, and as shown in Fig. 2.

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(24) Fig. 1 shows a horseshoe-shaped tank I have placed inside an incubator for

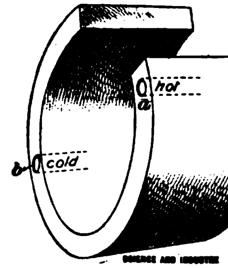

Fig. 1

heating it. I have connected my heater to this tank as follows: I ran a pipe from top of heater to the side of an expansion tank. From the bottom of the expansion tank I ran a pipe and connected it with the opening *a* of the tank. From the opening *b* I ran another pipe and connected it to the bottom of the heater. The heater and the expansion tank become very hot but there is no circulation through the horseshoe heater. What is the trouble? E. S. A., Marrietta, Ohio.

Ans.—Our correspondents submitted other sketches which are not clear enough for us to understand. We cannot therefore definitely state what is the trouble with his arrangement. However, Fig. 2 shows how

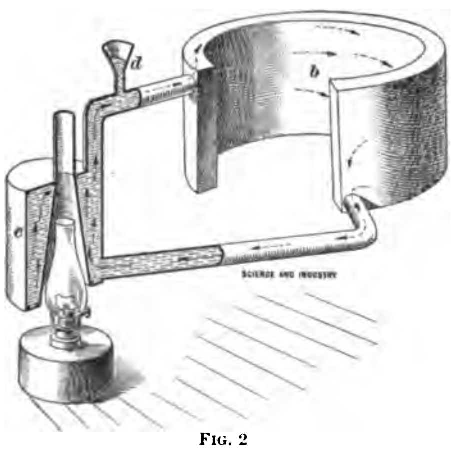

Fig. 2

such a tank may be connnected up in a very simple way so that a good circulation may be obtained between the tank *b* and the heater *c*. It is a center loop with an open expansion tank *d* connected to its highest point for filling the apparatus and for allowing air to escape. This expansion tank allows for expansion of the water when it is heated and is necessary for such an apparatus. The arrows show the general direction of the circulation. The pipes are graded so that any air inside the apparatus can rise and escape from the expansion tank.

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(25) (*a*) How can I take a picture with an ordinary hand camera to resemble the one here given? This is a clipping from a newspaper. (*b*) How can I proceed to solder iron, using borax as a flux? I have tried several times with no result. (*c*) What is the best book treating on character building?

S. T., Houston, Texas.

Ans.—(*a*) A photograph of the person is first taken by the ordinary process. This photograph is then photographed upon a sensitized copper plate and the lines etched out, making what is called a half tone, and this half tone is used by the printers to reproduce the picture such as you submitted. Half tones are made by persons who make a business of their manufacture, and you would probably have difficulty in attempting to make one yourself. (*b*) See Home Study Magazine for December, 1898, question 514. Use borax which has been melted and broken to a coarse powder. (*c*) "Character," by O. S. Marden; published by the Success Co., New York, N. Y.

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(26) What are the ingredients of solder such as is used for sealing condensed milk cans? L. K., Waterbury, Conn.

Ans.—Solder such as is used for sealing condensed milk cans is made of equal parts of lead and tin. It is important that the ingredients used should be as pure as it is possible to obtain, and any dross that forms on the surface when they are melted should be removed.

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(27) Please give me the title of a good book on concentrating machines.

H. C. J., Gold Hill, N. C.

Ans.—You will find some practical information in a concise form on this subject in The Coal and Metal Miners' Pocket Book. This can be secured from the Technical Supply Co., Scranton, Pa. Price $3.00.

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(28) Given a circle of known area *A*. Required the radius of a circle whose center is on the circumference of *A*, and whose circumference where it intersects *A* will divide *A* into two parts.

G. A. N., New York City, N. Y.

Ans.—See the Mechanic Arts Magazine for March, 1899, page 88, in which this problem is fully solved. Same can be had by remitting 10 cents to this office.

SCIENCE AND INDUSTRY

Vol. VII February, 1902 No. 2

STEAM ENGINE TESTING

WALTER B. GUMP

MANY articles have appeared from time to time in the engineering press in reference to the steam engine, its design, operation, and economy, but comparatively few have contained much information on the methods employed in a trial test. It is of great importance in power plants to know what amount of coal is used to produce a given amount of power. The electrical engineer should have as much interest in the amount of coal consumed as the steam engineer, for the more efficient the engine, the greater will be the electrical output. It is the purpose of this article, therefore, to give some of the practical points which are essential in the testing of a steam engine, and to show the ordinary way in which such a test is conducted.

At the outset we should have well fixed in mind the object of the test. There are usually four things sought after: (1) the amount of coal consumed per horsepower per hour; (2) the amount of dry steam used per horsepower per hour; (3) the number of heat units evolved from the fuel and used to generate the steam, and (4) the ways in which part of the heat is lost.

In some cases it is desirable to ascertain a fifth unknown quantity; namely, the mechanical loss due to friction; in other words, the friction horsepower. This is easily found, as will be shown later. The first four are more difficult problems, and will be treated at some length.

Before considering the first let us investigate for a moment what takes place in the boiler generating the steam, and the ways in which part of the heat units evolved from the coal are lost, and become unavailable for doing work. When combustion is perfect, one pound of pure carbon should yield about 14,500 B. T. U. (British thermal unit), 1 B. T. U. being equivalent to the amount of heat necessary to raise 1 pound of water 1° F. The mechanical equivalent of heat which was originally determined by Joule, and afterwards corrected by Prof. Rowland, is 778 foot-pounds of work, therefore, the theoretical number of units of work which should be obtained from 1 pound of pure carbon is

$$14,500 \times 778 = 11,281,000 \text{ ft.-lb.}$$

One horsepower $= 33,000$ ft.-lb. of work per minute, so that work done per hour $= 60 \times 33,000 = 1,980,000$ ft.-lb., therefore 1 pound of coal should be capable of producing

$$\frac{11,281,000}{1,980,000} = 5.697 \text{ H. P.}$$

per hour, provided that all of the heat is utilized in doing work.

It may easily be shown by mathematics that only a very small portion of this amount can be used in doing useful work. In the first place a

portion of it is lost through radiation, another portion by conduction, but a much greater quantity than either of these is lost in the engine cylinder by condensation of the steam itself. A very important problem to the steam engineer is cylinder condensation, and until we shall be able to operate our steam engines by means of superheated steam we cannot hope to remedy this fault very materially.

The best simple engine is capable of using only about 8 per cent. of the total heat supplied by the coal. A triple expansion engine will run up to 15 per cent. efficiency, which obviously shows the advantage of compounding, but even then we have 85 per cent. of the heat escaping, and beyond recovery for doing work.

In order to ascertain the amount of coal used per horsepower per hour, the amount of steam generated per pound of coal must be found, and in order to do this with any degree of accuracy a boiler test should be made, after which the engine should be indicated. As the present article deals only with the testing of the engine, it is out of place here to go into boiler testing. The coal value is only approximate at best, so that it is best to assume such a value as the boiler rating warrants, and accept corresponding results. Having these two values it is evident that the coal used per I. H. P. hour is very easily found.

It is necessary to know the condition of the steam in order to determine the losses, the greatest of which is condensation in the cylinder and piping. By the condition of steam we mean the quality of steam which is the percentage of dryness. This can be found only by a a careful test with a steam calorimetor, which will be described shortly. To find the percentage of condensation, the amount of dry steam used per horsepower per hour, the steam used per hour, and the I. H. P. must be known.

The latter is of course computed directly from the indicator card. The amount of dry steam used per horsepower per hour is found by first determining the total amount of steam used per I. H. P. per hour and then subtracting the percentage of moisture in the steam as shown by the calorimeter.

The heat used (B. T. U.) per horsepower per hour is found by first ascertaining the amount of steam per horsepower per hour taken from the boiler, and then multiplying each pound of steam by the total heat value of one pound at the corresponding temperature as given in the steam table.

The thermal efficiency of a steam engine, may be expressed by the formula,

$$E = \frac{T_1 - T_2}{T_1},$$

in which

E = the efficiency;

T_1 = absolute initial temperature of the steam;

T_2 = absolute final temperature of steam.

Before describing the test it may be well to explain the use of the apparatus employed. Most of us are more or less familiar with the steam engine indicator, and much depends upon the observation of the cards if the results are to be reliable. It is a well known fact that no two persons will observe the same thing in the same way. With regard to readings on scientific instruments, or even on a common draftsman's scale, the results of personal observation will vary. Therefore errors are found to creep into the results of a test such as the one that concerns us here.

On account of these errors of observation it may readily be seen that the

greater the number of readings taken, the greater will be the accuracy of the results, and when such a test is once under way there should be a sufficient number of men employed to have each man stationed at his assigned place and remain there until the end of the test, manipulating the same piece of apparatus, and recording the same class of readings.

Referring now to indicator cards, let us observe the one shown in Fig. 1. It becomes necessary to determine the exact point of cut-off on the card in order to make the computations. In this particular card the point of cut-off is at the point C, since the drop is more abrupt at this point than any other on the admission line. In Fig. 2 we have a card which is more puzzling; in fact, it is not a good card and shows either poor valve-setting or a poor indicator. If, however, such a case presents itself and we wish to find the point of cut-off, it can best be found in the following manner:

Starting from the admission line A and tracing the line toward the left, we find a slight hump at C; now through this point draw a horizontal line a; from there follow the line to the next hump C' and then to the next, where the expansion line changes direction, drawing horizontal lines through these points. If we observe

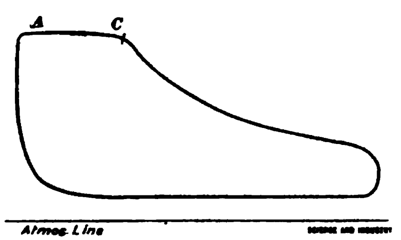


Fig. 1

the card now we can easily see that the slope of the expansion line from C' to C'' is much greater than it is from C to C'; therefore, C' is the most probable point at which the valve closed and the steam started to expand.

If a careful test is to be made it is advisable to make the time not less

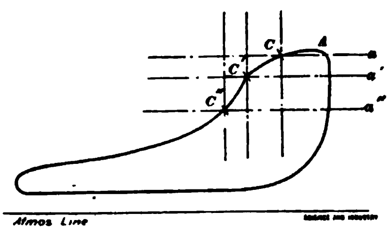


Fig. 2

than twelve hours duration, and twenty-four hour tests are often made.

When a twenty-four hour test is to be made, it is often necessary to have more than one shift of men, as a test of this kind is extremely tedious and tiresome. The readings ought to be taken at least every ten minutes, and on a short test every five minutes is better.

Before going further let us consider the steam calorimeter which is used to determine the amount of moisture in the steam. This value is expressed more commonly as a percentage of dryness than as a percentage of moisture. It is of the utmost importance to have a clear understanding of the principles underlying the calorimeter in order to use it, and the greatest care is required to be able to obtain even fair results. There are several types of calorimeters, among which may be mentioned the barrel, the separator, and the throtting calorimeter.

The barrel calorimeter is the simplest in construction and consists merely of a barrel which contains from 300 to 400 pounds of water. The steam is led into this water and condensed, being conveyed down through a pipe which is curved into a hook at the end. The apparatus is weighed before the steam is led into it, and is again weighed at the end of the test, the initial and final temperatures of the water being

taken. From this data the percentage of moisture may be computed. As this calorimeter is scarcely ever used outside of boiler testing we shall not consider it further.

The separator calorimeter is as simple in construction as any, and gives good results when carefully used. For this reason it has won a good deal of favor, and fully justifies a detailed description. When using this instrument it is not necessary to record any temperatures, as will be obvious from the following explanation: Referring to Fig. 3, let S represent the pipe containing the steam lead in from the main pipe. The end of this pipe is perforated, and is seen to extend a little over half way down into the hollow cylinder (a large piece of pipe) H. G is a water gauge glass, and C' is a cock which allows the condensed steam to be collected and weighed. It is obvious that the steam rushing in through the perforated pipe will have considerable inertia; furthermore, the only outlet this steam has is through the small orifice O in the pipe F, therefore the moisture in the steam will be deposited and collected in the calorimeter, and only dry steam will escape through the small orifice. The weight of condensed steam divided by the total weight of steam sent through the calorimeter will be the percentage, or rather the fraction, of moisture in the steam.

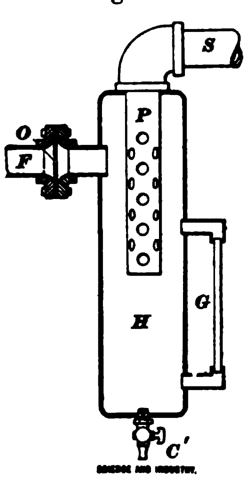


FIG. 3

There will be a portion of condensation due to radiation from the walls of the calorimeter, so that it is advisable to use two calorimeters, the escaping steam of the first passing into the second. The water (condensed steam), which is accumulated in the second, will be due entirely to radiation, since dry steam entered it.

Before commencing the test, steam must be run through, and the calorimeter brought up to a constant temperature. The water level in the gauge should be marked by placing a thread on the glass, and at the close of the test the water should be drawn off until this same level is reached. It is well to state here that the calorimeter—no matter what kind is used—should be thoroughly lagged with hair-felt or asbestos, in order to reduce the loss by radiation to a minimum.

The following formula expresses the quality of steam as found by this form of calorimeter:

$$Q = \frac{W + R}{W + w},$$

where $Q =$ dryness of steam (expressed as a fraction);
$W =$ wt. of dry steam discharged through the calorimeter;
$w =$ wt. of water drawn off;
$R =$ water condensed by radiation;

the latter value being found by the second calorimeter as was explained.

We shall now describe the throttling calorimeter, which may be used to great advantage and with accuracy provided the percentage of moisture does not exceed 3 per cent. It is interesting to look into the principle on which the throttling calorimeter operates, and when once this is fixed in mind the formula in connection with it may be derived without difficulty. It is well known that when steam is expanded without performing work the steam superheats. Now suppose that this steam is not perfectly dry to begin

with, but contains a small percentage of moisture in suspension; then, when the steam is expanded—as through a small orfice—it will superheat up to a point which is limited by the quantity of moisture contained in the steam; that is, the more moisture the steam contains the less will it superheat, for this moisture must be reevaporated, and to do this heat is required; thus, an excess of moisture will prevent superheating entirely.

It is therefore evident that an excess of moisture cannot be accounted for by any equation that could be used, as the degree of superheating is the basis of our formula.

The general form of throttling calorimeter is shown in Fig. 4, and consists simply of a pipe containing a disk into which a small hole—about $\frac{1}{16}$ in.—has been drilled. Steam, which is brought into the calorimeter passes through this orifice and is expanded, causing the steam to superheat as explained. We know that the live steam (entering steam) contains a quantity of heat equal to the total heat of evaporation less the percentage of moisture; that is, for every pound of steam evaporated in the boiler there will be $H - \frac{XL}{100}$ B. T. U., when $L =$ the latent heat at the given pressure and temperature. Now, when steam condenses it gives up its latent heat of evaporation, so that the amount of latent heat it gives up is proportional in this case to the percentage of moisture.

On expanding this steam through the orifice we have the steam containing the total heat of evaporation (for it must be reevaporated), plus the heat above boiling point at atmospheric pressure, 212° F. The latter quantity is equal to the specific heat of steam times the rise in temperature. The specific heat of dry steam is about .48. This gives us the second member of the equation, or, expressing it in words: the heat given up by the entering steam is exactly equal to the heat taken up by the steam in superheating. Algebraically,

$$H - \frac{XL}{100} = 1146.6 + .48\ (t - 212),$$

from which

$$X = 100 \times \frac{H - 1146.6 - .48\ (t - 212)}{L}.$$

The last two calorimeters just explained are as reliable as any, and it is needless to make mention of any others. It is advisable to use two calorimeters in combination, so that one may check the results of the other. This, of

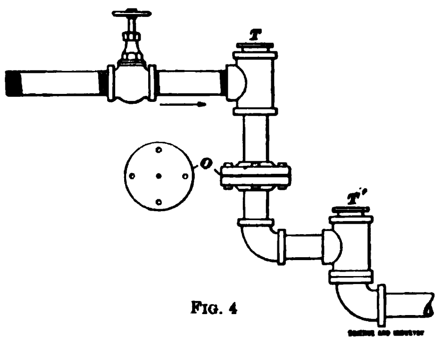


FIG. 4

course, is a matter for the individual to decide, since he is familiar with the local conditions concerning the test.

After we have found the percentage of moisture, we are able, with the aid of the cards taken, to compute the cylinder condensation. In order to do this we must first know the average point of cut-off as taken from the total number of cards recorded during the test. Suppose, for example, that the average point of cut-off is three-eighths of the stroke. The amount of steam by weight which has passed through the cylinder has been found by condensing and weighing it. From this we can find the quantity of steam used per stroke, knowing the speed at which the engine is running. This steam is wet, and will occupy less volume

than steam of the same weight which is dry. Knowing the volume of the cylinder, first compute the volume of the steam at cut-off, which, in the assumed example, will be three-eighths the total volume + clearance. The next thing to do is to compute the weight of steam per stroke, which will be, of course, the weight of steam at three-eighths cut-off. Having found this, refer to the steam table and find the volume this weight should occupy

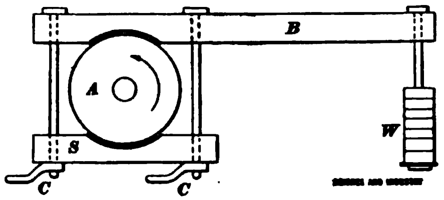


FIG. 5

if the steam were dry, and at the pressure recorded by the indicator.

Then, $D : D_1 = V : V_1$,

where D = per cent. actual dryness at cut-off in cylinders;

and D_1 = 100 per cent. dryness;

V = volume in cylinder at cut-off;

V_1 = volume of same weight of *dry* steam.

$$\therefore D = \frac{\text{Vol. in cylinder at cut-off} \times 100}{\text{Vol. same weight dry steam}}$$

This formula does not account for the percentage of moisture in the steam pipe; therefore, to get the amount due to condensation alone we must subtract the per cent. of moisture found by the calorimeter.

Since the above formula expresses the condition as per cent. dryness, the per cent. moisture will be simply

$$100 - \left[\frac{\text{Vol. in cylinder} \times 100}{\text{Vol. same wt. dry steam}}\right] - P$$

where P is the per cent. moisture given by the calorimeter.

The foregoing matter has shown the steam calculations; now let us consider some other factors, such as the friction horsepower and the developed horsepower.

The friction horsepower is the horsepower which the card indicates at no load; that is, it is the power used in overcoming the friction of the parts, and the resistance offered by the air to the flywheel, and the other reciprocating elements. The I. H. P. may be calculated from the formula

$$H.\ P. = \frac{Plan}{33{,}000} \text{ in which}$$

P = the M. E. P. (mean effective pressure) in pounds per square inch on the piston;

l = the length of stroke in feet;

n = number of single strokes per minute;

a = the area of the piston in square inches;

and since 33,000 ft.-lb. per minute equals one H. P., dividing by this number will give the horsepower.

The developed horsepower is a name given to the horsepower under a given load, as indicated, less the friction horsepower, or it is the total I. H. P. minus the I. H. P. at no load. From this it is obvious that the I. H. P. is simply the horsepower given on the card under the normal load.

The brake horsepower is the horsepower which is necessary to overcome the mechanical friction of a brake commonly called a prony brake. This piece of apparatus is shown in Fig. 5, which is a typical form of brake used. In the figure A is the pulley of the brake. This may be the main pulley, as it is in the case of a motor or dynamo. In engine testing, however, it is usually a separate pulley used especially for the brake. B is a wooden arm of a convenient length, say from 3 to 5 feet. S is a wooden piece clamped to the pulley by the fasteners C C. At the end of the arm B are suspended weights W which pull on the arm just

enough to balance (or not quite equal) the torque in the direction of the arrow. Now, since work is the product of the force acting, and the distance through which it acts, the brake horsepower will be expressed by the formula

$$B.\ H.\ P. = \frac{2\ \pi\ r\ n\ w}{33,000} \text{ in which}$$

r = the radius of the arm in feet from center of pulley to weight;
n = number of single strokes per min.;
w = the weight in lb. on the arm.

This form of brake is much used, as it is simple in construction, is easy to operate, and affords a convenient method of placing a trial load on an engine or electric motor.

Thus far nothing has been said in regard to the method of weighing the condensed steam as it passes out of the condenser. This is a simple operation, and yet it requires careful attention and forethought. Referring to Fig. 6, suppose the steam (which is condensed) passes out into the tank A. This we may call the supply tank, and it should be of a sufficient size not to overflow between readings of the test. From this tank the water is drawn off into tank B, the weighing tank.

After each reading, the weight of the tank after the water has been released must be carefully noted, and must be subtracted from the total weight. The weight of the tank, will vary some because the quantity of water which adheres to the tank is never the same for two readings.

When making the test it is desirable to record the amount of cooling water used in the condenser, as this is sometimes quite an important item. The cooling water may be weighed, and accounted for, in the same manner as the condensed steam just described.

In conclusion a few words might be said in relation to the testing of compound engines, since the foregoing alludes entirely to simple engines. There are several things to be accounted for which do not appear in the case of a simple engine. First let us suppose we are testing a tandem compound engine. It will be seen on investigation, that cards (one for each cylinder) must be taken simultaneously in order to indicate the total horsepower. There will be a heat loss between cylinders which should be considered also, in

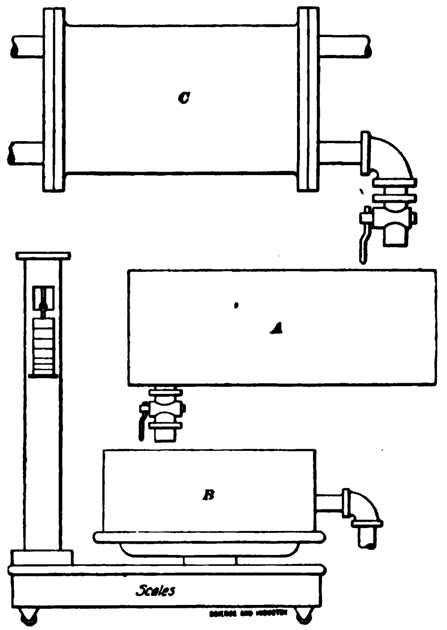


FIG. 6

order to compute the cylinder condensation accurately, so that we have practically two engines to look out for, besides intermediate losses.

If the engine is a cross-compound it becomes necessary to start a card at the beginning of the stroke of each cylinder, since the cranks will be quartered. The total horsepower of any engine, simple or compound, is the sum of the I. H. P. on both the cards of each cylinder. In the cross-compound there is condensation in the receiver to be accounted for. This

may be computed by regarding the receiver as a cylinder and proceeding by the method of volumes and weights, as previously demonstrated.

The testing of compound engines should be dealt with separately, and cannot claim more space here. A certain amount of experience is necessary in any case, but it is hoped that these statements regarding engine testing have brought some new ideas to the student, and have reminded the steam engineer of a few things he may have forgotten.

Before closing, the writer wishes to call attention to a table showing a short test which was conducted in the Steam Laboratory of Pratt Institute, in 1898, and affords an example of the list of values usually tabulated. These values in themselves amount to but little and in fact are far from correct. The table is intended only as a general example and must not be considered otherwise.

REPORT OF ENGINE TEST TAKEN IN THE STEAM LABORATORY, PRATT INSTITUTE, BROOKLYN, N. Y.

Duration of Test 1 Hour

Small Horizontal Engine	*Crank End*	*Head End*
Piston displacement, cubic feet	1,290	1,336
Clearance	10%	10%
Cut-off, per cent.	76.5%	39.8%
Steam-pipe pressure	77.5	77.5
Initial pressure	63.5 lb. (abs.)	61.8 lb. (abs.)
Pressure at cut-off	32.5	33.9
Weight of steam at cut-off	.01413 lb.	.01358 lb.
Back pressure	17.4 lb.	16.5 lb.
Compression, per cent.	57	60
Weight of steam at compression	.00248	.00243
Weight of water per hour	336.9 lb. total	
Weight of water per stroke	.01164	.01112
Per cent. moisture at cut-off	33	31
M. E. P.	31 lb.	24 lb.
Initial condensation, per cent.	30	32
Theoretical efficiency	31.4	32.2
I. H. P.	4.1	3.5
R. P. M.	320	
B. H. P.	4.2	
Water (condensed steam) per H.P. per hour	56.12	
Moisture in steam pipe	1%	
Heat supplied per H. P. hour	47,955 B. T. U.	
Heat equivalent of 1 H. P. hour	2,621	
Thermal efficiency	60%	
Efficiency compared to perfect engine	52	
Mechanical efficiency	74%	

CUT-GLASS WORK

THE glass vessel is first blown out to the proper shape in the mold. After it cools the general lines of the pattern to be cut out on its surface are drawn on it by means of colored chalk or paint. The pattern is then cut on the glass by means of a steel wheel on which a stream of fine sand is constantly flowing from a trough immediately above the wheel. This process gives a kind of rough or frosted appearance to the pattern. To get rid of this and smoothen the pattern out it is gone over with a stone cutter. This is a stone wheel with a beveled edge which is kept sharp by going over it with a flint two or three times a day. The last process through which the pattern is carried is smoothing by means of wooden wheels. After this the vessel is ready for the market.

POINTS ON THE SELECTION OF BOILERS

CHAS. L. HUBBARD

VERY few manufacturers and steam users are competent engineers, and they are therefore not always capable of the best judgment in matters relating to the merits or shortcomings of the boilers offered them by different makers. If a manufacturer has a 300-horsepower engine, he may order 300 horsepower of boilers to run it, without having a very clear idea of what 300 horsepower means in either case. Although a horsepower has a difinite meaning in each instance, it does not follow that a boiler horsepower is equal to an engine horsepower.

A boiler of 100 H. P. may supply sufficient steam for a 200 H. P. compound condensing engine of best make with Corless valve gear, or it may only be able to provide steam for a 50 or 75 H. P. engine of old style with a plain slide valve. In each case the boiler would be delivering the same amount of steam and be running at its normal rating of 100 H. P.; but the work delivered by the engine would vary from 50 to 200 H. P., depending on its water rate.

An engine H. P. means *work*, to the amount of 33,000 foot-pounds per minute, while a boiler H. P. means *steam*, to the amount of 30 pounds per hour at a pressure of 70 pounds, and from a feedwater temperature of 100° F. The amount of heat required to evaporate 30 pounds of water into steam under the above conditions is the same as that required to evaporate 345 pounds from a temperature of 212 degrees into steam at atmospheric pressure, which is $34.5 \times 966 = 33,327$ heat units, which for practical purposes is commonly taken as 33,000.

The fact that 33,000 foot-pounds of work per minute represents an engine H. P. and 33,000 heat units per hour a boiler H. P. often leads to more or less confusion among those who are not thoroughly familiar with the meaning of the term as applied to the two cases under consideration. Let us turn again to the nominal rating of a boiler and see what conditions of construction are necessary in order that it may evaporate the given amount of steam required of it. It has been found by experience that in well proportioned tubular boilers 1 square foot of heating surface will evaporate, under ordinary conditions, about 2.3 pounds of water from a temperature of 212 degrees into steam at atmospheric pressure, which corresponds to 15 square feet of heating surface per H. P. $(34.5 \div 2.3 = 15)$.

From the fact that with careful firing a boiler may be made to considerably overrun its rated capacity, some makers rate their boilers at 1 H. P. for each 11½ or 12 square feet of heating surface; 11 is a common figure for water-tube boilers, which are more efficient for a given amount of heating surface than tubular boilers.

In computing the heating surface of a horizontal tubular boiler it is customary to take ½ the area of the shell plus ⅔ the rear head less the combined area of the tubes, plus the interior surface of all the tubes.

The number, size, and arrangement of the tubes has a marked effect upon the efficiency of the heating surface. The fact that a boiler has 1,500 square feet of heating surface does not by any means signify that it will develop 100 H. P. I have before me at the present time two tables of boiler ratings, one of which gives a 60 H. P. boiler as one 60 inches in diameter

and having 94 3-inch tubes 12 feet long, Fig. 1; while the other calls for 72 3-inch tubes 15 feet long, Fig. 2.

A glance at the figures will show at once the superiority of the latter.

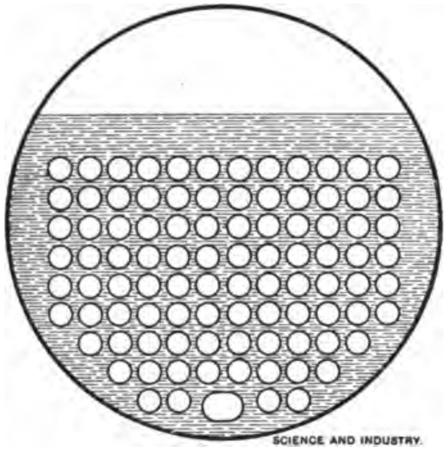


FIG. 1

There is an ample space for the circulation of the water next to the shell of the boiler with a 2-inch vertical space between the rows of tubes at the center.

Plenty of room is left above the tubes for the separation of the steam from the water, thus insuring drier steam than in the other case. More room for inspection and for making repairs is provided in the second case than in the first, which is another advantage. When the tubes are placed too near the shell there is danger of grooving caused by unequal expansion. The greater length of the tubes in the second boiler will give greater economy in the use of fuel, as more opportunity is offered for the absorption of heat from the gases than in the case of the shorter ones. A boiler of the proportions shown in Fig. 2 should easily develop a H. P. 30% or more in excess of its rated capacity if necessary, without a wasteful use of fuel, while in the case of Fig. 1, with the shorter length of tubes and limited steam space, any such attempt would be likely to result in a waste of fuel and the delivery of steam loaded to a greater or less extent with moisture.

The following table may be used as a guide in selecting a boiler for a given H. P. These sizes are based on a rating of 15 square feet of heating surface per H. P. and give what experience has shown to be a desirable number of tubes for the different sizes.

Diameter of Boiler. Inches	No. of Tubes	Diameter of Tubes. Inches	Length of Tubes. Feet	Horse-power
30	28	2½	6	8.5
			7	9.9
			8	11.2
			9	12.6
			10	14.0
36	34	2½	8	13.6
			9	15.3
			10	16.9
			11	18.6
			12	20.9
42	34	3	9	18.5
			10	20.5
			11	22.5
			12	24.5
			13	26.5
			14	28.5
48	44	3	10	30.4
			11	33.2
			12	35.7
			13	38.3
			14	40.8
			15	43.4
			16	45.9
54	54	3	11	34.6
			12	37.7
			13	40.8
			14	43.9
			15	47.0
			16	50.1
	46	3½	17	53.0
60	72	3	12	48.4
			13	52.4
			14	56.4
			15	60.4
			16	64.4
	64	3½	17	71.4
			18	75.6
66	90	3	14	70.1
			15	75.0
			16	80.0
	78	3½	17	86.0
			18	91.1
			19	96.2
	62	4	20	93.1
72	114	3	14	87.4
			15	93.6
			16	99.7
	98	3½	17	106.4
			18	112.6
			19	118.8
	72	4	20	107.3

The material and thickness of the plates, type of riveted joints, etc., are matters of much importance and should be carefully inquired into.

Mild steel is almost wholly used at the present time for boiler plates. It should have a tensile strength of not less than 55,000 pounds nor more than 60,000 pounds per square inch with not less than 56% of ductility. A sworn statement of the results of tests made by the manufacturers of the plates giving the above data will be furnished by the boilermaker upon request. Ordinarily, $\frac{1}{16}$ of an inch at least should be added to the required thickness of the plates to offset the effects of corrosion.

For power work the double, or better, the triple, riveted butt joint should be used.

The following table gives thicknesses of shell for boilers of different diameters, with both double and triple riveted butt joints. These figures are for a working pressure of 100 pounds per square inch and a factor of safety of 6. To these thicknesses should be added $\frac{1}{16}$ of an inch or more for the effects of corrosion, depending upon the quality of the feedwater to be used.

Diameter of Boiler. Inches	Thickness of Shell, Double-Riveted Butt Joint. Inches	Thickness of Shell. Triple-Riveted Butt Joint. Inches
30	$\frac{1}{4}$	$\frac{1}{4}$
36	$\frac{1}{4}$	$\frac{1}{4}$
42	$\frac{5}{16}$	$\frac{5}{16}$
48	$\frac{3}{8}$	$\frac{5}{16}$
54	$\frac{3}{8}$	$\frac{3}{8}$
60	$\frac{7}{16}$	$\frac{3}{8}$
66	$\frac{7}{16}$	$\frac{7}{16}$
72	$\frac{1}{2}$	$\frac{7}{16}$

Another important factor in the successful operation of a boiler is the size of the grate. This depends to a large extent upon the rates of combustion and evaporation and also bears a certain relation to the heating surface.

Theamount of coal burned per square foot of grate surface per hour varies with the draft, the kind of coal used, and the care taken in firing.

With power boilers having chimneys of good height the amount is rarely less than 15 pounds. While from 8 to 10 pounds is a fare average for heating boilers of good size.

The rate of evaporation in well pro-

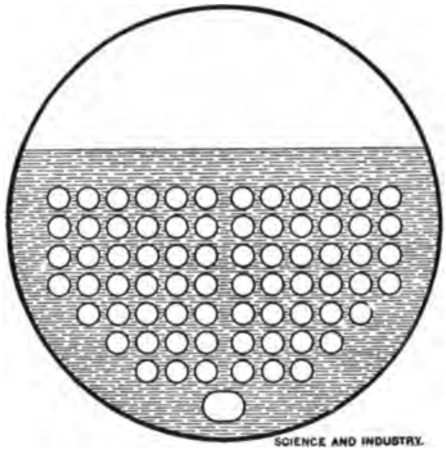


FIG. 2

portioned boilers with clean tubes may vary from 8 to $10\frac{1}{2}$ pounds of steam per pound of coal; 9 pounds may be taken as a fair average. The square feet of grate surface required per H. P. may be computed from the expression

$$\frac{34.5}{\text{rate of combustion} \times \text{rate of evaporation}}$$

for the weight of steam per pound of coal, multiplied by the pounds of coal burned per square foot of grate surface, will give the weight of steam evaporated per square foot of grate surface per hour; therefore, 34.5 divided by this quanity will give the square feet of grate surface required per H. P.

Inserting in this formula the values already given we have $\frac{34.5}{9 \times 15} = .26$ or call it .3 of a square foot of grate surface per H. P.

Another method of computing the grate area is as follows: It has been found from experience that a combustion of about $\frac{1}{4}$ of a pound of coal per

square foot of heating surface seems to give the most satisfactory results, so if we divide the total heating surface of the boiler by 4 and divide the result by the probable rate of combustion it will give us the required grate area.

A very important point to be taken into consideration is whether the plant shall be designed so that the boilers will do their work with slow fires under them, or have to be forced, in order to keep the plant in operation. Which of these is the most economical in the long run is the question which interests steam users. If a small boiler plant is installed and run to its utmost capacity, the original cost of boilers and the ground on which to locate them, the interest account, and cost of insurance will be comparatively small; but when economy of fuel, durability of boilers, cost of repairs, and ability to run continuously are to be taken into consideration, the advantages are in favor of the larger plant. The point which I have wished to bring out is this —do not purchase a boiler depending solely upon the builders' rating. First determine the amount of steam required by your engine, allowing for any extra amount required for pumps, heating coils, etc., and then call for a boiler of such dimensions as experience has shown will economically furnish the quantity of steam required.

Various matters of detail, such as material and thickness of plates, riveted joints, etc., should also be carefully looked after. A certain amount of practical knowledge on the part of the purchaser may often save a large amount of money and endless annoyance.

SIMPLE LESSONS IN ALTERNATING CURRENTS—IX

IN THE last lesson some examples were given of the behavior of alternating currents in circuits where either self-induction or capacity is present. We will now see how these influence the value of the current and how some of the simpler calculations connected with alternating currents may be made. Self-induction tends, as it were, to choke back the current and make it lag behind the electromotive force. On the other hand, the effect of capacity is exactly the opposite. As circuits containing resistance and self-induction are much more commonly met with than those containing resistance and capacity, we will for the present confine our attention to the former.

If current is flowing through any circuit that contains resistance and self-induction, say, for example, a coil of wire wound on an iron core, an induction motor, primary of a transformer, or any other device of a similar kind, the ohmic resistance, i. e., the resistance that depends upon the conductor itself, tends to prevent the flow of the current, but it does not tend to displace the E. M. F. and current in their phase relations. In considering the flow of current through circuits containing resistance and self-induction, it is convenient to think of the resistance and self-induction as setting up counter E. M. F.'s that are opposed to the E. M. F. supplied by the alternator. The E. M. F. supplied by the alternator or other source must, then, in the case of alternating-current circuits, overcome not only the resistance, but also the self-induction. In the case of continuous-current circuits, the resistance alone need be taken into account. In every case, then, where an impressed E. M. F. (the E. M. F. applied

to, or impressed, on the circuit) encounters both resistance and self-induction, it may be looked on as being split into two parts; one of which is necessary to overcome the resistance and the other the self-induction.

That part of the applied E. M. F. that is required to overcome the resistance is obtained by multiplying the current by the resistance, because from Ohm's law $C = \frac{E}{R}$, or $E = CR$. It is evident that when the current is zero, the E. M. F. necessary to overcome the resistance is also zero, because there is no current to force through the resistance. Also, when the current is at its maximum value, the E. M. F. required to overcome the resistance is at its maximum value. *The E. M. F. required to overcome the ohmic resistance is, therefore, in phase with the current.*

The part or component of the applied E. M. F. that is necessary to set up the current against the induced E. M. F., or, in other words, to overcome the self-induction, is at right angles to the current and is 90°, or one-quarter of a cycle, ahead of the current in phase.

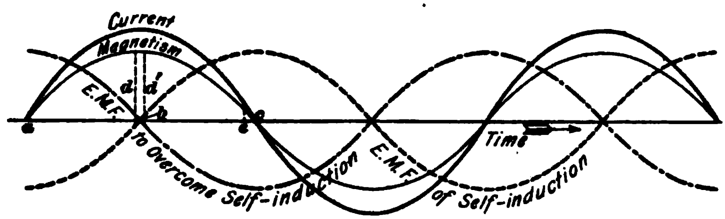


FIG. 1

This may be seen by referring to Fig. 1, where the heavy line wave represents the current flowing in a coil or circuit. The varying magnetism that threads the circuit and which is the cause of the induced E. M. F., will increase and decrease with the current, and, hence, may be represented by the light line wave in phase with the current. Now the *induced E. M. F.* is greatest when the magnetism is changing at its most rapid rate, because then the cutting of the lines of force by the circuit is greatest. If the reader will examine the curve that represents the varying magnetism, he will notice that when the curve is at its highest point the magnetism is changing but little; for example, there is little or no change between the lines *d*, *d'* as these two lines are of about the same length. On the other hand, when the magnetism curve is passing through zero, a small change in time, as, for example, from *e* to *c* is accompanied by a considerable change in magnetism, because the magnetism decreases from the amount at *e* to zero. In short, the rate of cutting the lines of force or the *rate of change* of the magnetism is greatest when the magnetism is passing through zero; hence, the *induced* E. M. F. must be a maximum when the current and magnetism are passing through zero. The induced E. M. F., therefore, differs in phase from the current by 90°. Also, when the current is increasing in a positive direction, the induced E. M. F. must be in the negative direction, because the induced E. M. F. opposes the increase in the current. The dotted curve, Fig. 1, must, therefore, be one-quarter of a cycle behind the full line curve as regards the direction in which time is laid off along the horizontal line. Now we are not so directly concerned, in the working of problems, with the induced E. M. F. itself as with the E. M. F. that must be applied to overcome the induced E. M. F. It is evident that this E. M. F. required to *overcome* self-induction must be the equal and

opposite of the E. M. F. *of* self-induction, and is, therefore, represented by the dot-and-dash curve, Fig. 1, which is 90° or one-quarter of a cycle ahead of the current in phase.

If we send an alternating current through a load of incandescent lamps

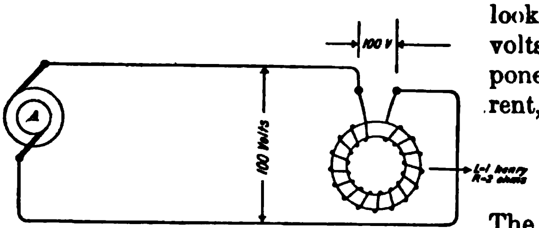


FIG. 2

or through a water rheostat, we have a circuit in which there is no self-induction, or it is a non-inductive load. Under such circumstances the current and E. M. F. will be in phase with each other, and the alternating current will behave in the same way as a direct current. We can apply Ohm's law to find out what E. M. F. will be required to force a given current through the resistance, or we can use the same law to find out what current will flow when a known E. M. F. is impressed or applied.

Suppose, however, that we apply an alternating E. M. F. of, say, 100 volts to a device having a resistance of 2 ohms and an inductance of 1 henry, as shown in Fig. 2. It will be remembered that the henry is the unit of self-induction and a device or circuit has an inductance of 1 henry when the magnetic flux set up through it by a current of 1 ampere multiplied by the number of turns is equal to 10^8 or 100,000,000. The device shown in Fig. 2 may be a choke coil made by winding a number of turns of insulated wire on an iron core. The wire itself has a certain amount of resistance and it is so wound that the conditions are favorable for a large amount of self-induction. Such being the case we cannot use Ohm's law to find out what current the 100 volts will set up. If it did follow Ohm's law, we would get a current $C = \frac{E}{R} = \frac{100}{2} = 50$ amperes. As before stated, we may look upon the applied E. M. F. of 100 volts as made up of two parts or components, one in phase with the current, and the other at right angles to it.

The part required to overcome the resistance and in phase with the current is equal to $C \times R$. The part at right angles to the current represents that necessary to overcome the counter E. M. F. of self-induction and this E. M. F. depends upon the inductance L, and the frequency n of the current, because the more rapidly the current changes the greater is the induced E. M. F. This induced E. M. F. is equal to $6.283 \times n \times L \times C$, where C is the current. The applied pressure furnished by the alternator must be the resultant sum of these two components. For example, in Fig. 3 let the line $o\,a$ indicate the direction of the current. Then the line $o\,b$ representing $C \times R$ in phase with $o\,a$ will represent the E. M. F. to overcome resistance, and $o\,c = 6.283 \times n \times L \times C$, 90° ahead of the current, will represent the E. M. F. necessary to overcome the counter E. M. F. of self-induction. The diagonal $o\,d$ of the parallelogram constructed on the sides $o\,b$ and $o\,c$ will represent the impressed E. M. F. E to scale. Since $b\,d$ is equal to $o\,c$, we may represent

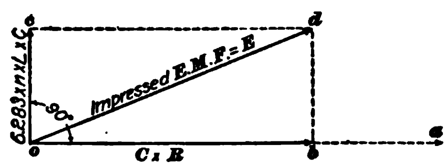


FIG. 3

these E. M. F.'s by the triangles shown in Fig. 4. Now since $o\,b\,c$ is a right-angled triangle, we know that $o\,c^2 = o\,b^2 + b\,c^2$, and since $o\,b = R\,C$ and $b\,c = 6.283\,n\,L\,C$ we have $o\,c^2 = (R\,C)^2 + (6.283\,n\,L\,C)^2$ or

$$o\,c = \sqrt{R\,C^2 + (6.283\,n\,L\,C)^2}$$
$$= \sqrt{C^2\,[R^2 + (6.283\,n\,L)^2]}$$
$$= C\sqrt{R^2 + (6.283\,n\,L)^2}$$

or since $o\,c = E$ we have,

$$E = C\sqrt{R^2 + (6.283\,n\,L)^2}$$

$$\text{and } C = \frac{E}{\sqrt{R^2 + (6.283\,n\,L)^2}},$$

Fig. 5 shows the relation of the values of the three E. M. F.'s that make up the triangle. The current lags behind the impressed E. M. F. by the angle a, and the last formula, i. e.,

$$C = \frac{E}{\sqrt{R^2 + (6.283\,n\,L)^2}},$$

gives the relation between the current

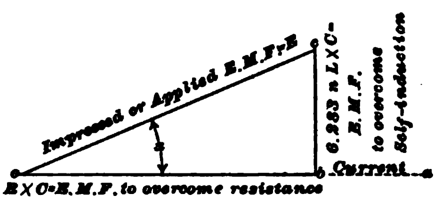


FIG. 4

and applied E. M. F. for any alternating-current circuit of which the resistance is R, the coefficient of self-induction or inductance L, and the frequency n, in other words, this formula is the shape which Ohm's law assumes for alternating currents, and it is of the utmost importance in calculating the flow of such currents. If we have a given E. M. F. we must divide it by the quantity

$\sqrt{R + (6.283\,n\,L)^2}$ in order to get the current or the quantity

$$\sqrt{R + (6.283\,n\,L)^2}$$

multiplied by the current is equal to the applied E. M. F. This quantity is called the *impedance* of the circuit, and for an alternating-current circuit we may, therefore, write

$$\text{current} = \frac{\text{applied E. M. F.}}{\text{impedance}}.$$

The quantity $6.283\,n\,L$, which, multiplied by the current, see Fig. 3, gives

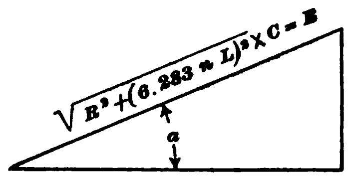


FIG. 5

the E. M. F. necessary to overcome self-induction, is called the *reactance* of the circuit. Both reactance and impedance are expressed in ohms, and the relation between resistance, reactance, and impedance is

Impedance =

$$\sqrt{\text{resistance}^2 + \text{reactance}^2}.$$

Now let us apply the above to the calculation of the current that will flow when the E. M. F. of 100 volts at, say, 30 cycles per second is applied to the coil. In this case $R = 2$ ohms, $L = 1$ henry, $E = 100$ volts, and $n = 30$; hence, we have

$$C = \frac{E}{\sqrt{R^2 + (6.283\,n\,L)^2}}$$
$$= \frac{100}{\sqrt{4 + (188.49)^2}} = .53 \text{ ampere. Ans.}$$

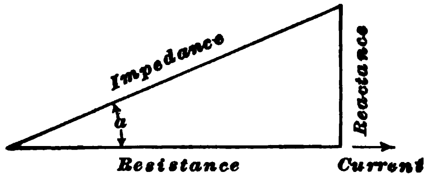


FIG. 6

We have already seen that if 100 volts were applied to this coil on a direct-current circuit that the current

would be 50 amperes, so the marked influence of the counter E. M. F. in choking back the current is easily seen, or, in other words, the impe-

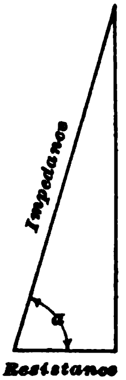


FIG. 7

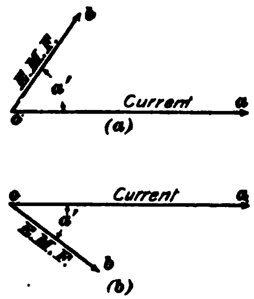


FIG. 9

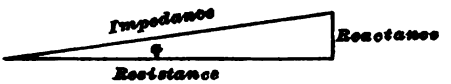


FIG. 8

dance is very much greater than the resistance.

The relation between resistance, reactance, and impedance is shown by the triangle in Fig. 6. If the reactance is large compared with the resistance, the triangle will take the shape shown in Fig. 7, the angle a by which the current lags behind the E. M. F. will be large, and the current flow will be determined largely by the reactance. If, on the other hand, the reactance is small compared with the resistance, as in Fig. 8, the angle of lag will be small, and the current will be determined largely by the resistance. If the reactance becomes zero, i. e., if either n or L becomes zero, or, in other words, if the current becomes continuous, or if the circuit is made non-inductive, the angle a becomes zero, the triangle reduces to a straight line, and the E. M. F. and current come into phase with each other.

The formula $C = \dfrac{E}{\sqrt{R^2 + (6.283\ n)\ L}}$ bears the same relation and importance to alternating-current problems that Ohm's law $C = \dfrac{E}{R}$ does to direct-current problems. As a further example of its application, take the following: Suppose an alternator that generates current at a frequency of 60 cycles sends a current of 10 amperes through a circuit that has a resistance of 10 ohms and an inductance of .05 henry; what E. M. F. must the alternator supply? In this case $C = 10$ amperes, $R = 10$ ohms, $L = .05$ henry, and $n = 60$; hence, we have

$$E = C\sqrt{R^2 + (6.283\,n\,L)^2} =$$

$10\sqrt{100 + (6.283 \times 60 \times .05)^2} = 213$ volts, approximately. Take another example: A 1,000-volt, 125-cycle alternator is connected to a circuit having a resistance of 10 ohms and an induction of .01 henry; what current will flow? In this case C is required; $R = 10$ ohms, $L = .1$ henry, $n = 125$ cycles per second. We have, then,

$$C = \frac{E}{\sqrt{R^2 + (6.283\,n\,L)^2}}$$

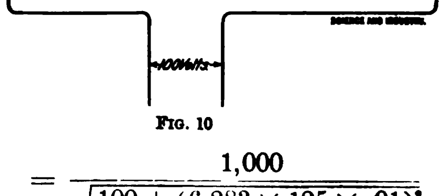


FIG. 10

$$= \frac{1{,}000}{\sqrt{100 + (6.283 \times 125 \times .01)^2}}$$

$= 78.6$ amperes. If this circuit were non-inductive or if 1,000 volts direct

current were applied to it, the current would follow Ohm's law and would be $\frac{1,000}{10} = 100$ amperes, instead of 78.6 amperes, thus showing the influence that the reactance has on the flow of the current.

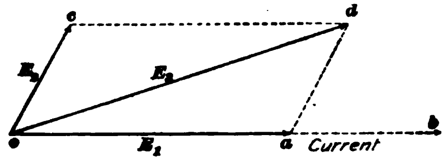


FIG. 11

The action of capacity in a circuit is exactly the opposite to that of self-induction. Self-induction makes the current lag behind the E. M. F., while capacity makes the current lead the E. M. F. It is possible, therefore, to have a circuit in which the effects of self-induction and capacity exactly neutralize each other. For example, in Fig. 9 (*a*), if *o a* represents the current, self-induction would make the current lag behind by the angle *a'*. Capacity, on the other hand, would make the current lead the E. M. F., as shown in Fig. 9 (*b*), or the E. M. F. would lag behind the current.

In the last lesson we gave some examples of the peculiar behavior of alternating currents and E. M. F.'s in circuits containing resistance, self-induction, and capacity. Take the case shown in Fig. 1 of the last lesson. This figure is here reproduced, Fig. 10, for convenience. The E. M. F. E_1 across the lamp will be in phase with the current, because *L* is a non-inductive resistance; hence, in Fig. 11, we can represent E_1 by the line *o a* in phase with the current, which is represented by *o b*. The E. M. F. E_2 across the inductive resistance *M* will be represented by some such line *o c* considerably ahead of *o a* in phase. The E. M. F. E_3 impressed by the circuit is the resultant of *o a* and *o c*, and is represented by the diagonal *o d*.

Now *o c* represents the voltmeter reading E_1, and *o a* the reading E_2, and it is easily seen that the impressed E. M. F. E_3 is less than the arithmetical sum of E_2 and E_1, and also that E_3 would be equal to the arithmetical sum of E_1 and E_2 only when E_2 and E_1 were in phase with each other, as would be the case if both *L* and *M* were non-inductive or if a direct current were sent through the circuit.

Take the case shown in Fig. 12, which is Fig. 4 of the last lesson repeated. In Fig. 13 let *o a* represent the direction of the applied E. M. F. *E*. The current in l_1 is the resultant of the currents in the two branches. The current in the inductive circuit will lag nearly one-quarter of a cycle behind

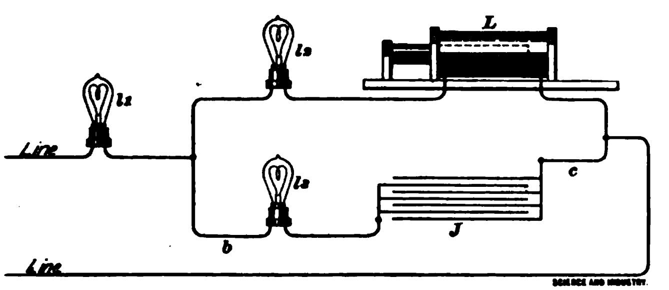


FIG. 12

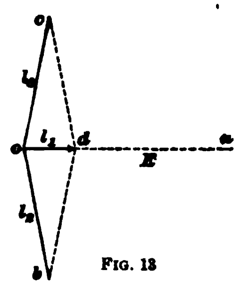


FIG. 13

the E. M. F., and will be represented by a line such as $o\,b$. The current in the condenser will be nearly one-quarter of a cycle ahead of the E. M. F., and will be represented by $o\,c$. L is supposed to be adjusted so that $o\,c = o\,b$. The current in lamp l_1 is, therefore, represented by the length of the line $o\,d$, and it is easily seen that because of the phase relation of $o\,c$ and $o\,b$, this current may be much smaller than either of the currents in l_2 or l_3 taken by themselves.

With these formulas and examples we will conclude our series of lessons on alternating currents. In them we have tried to give the reader an idea as to the nature of such currents, and the laws that govern their flow. In doing this we have confined ourselves to the simplest possible cases. We hope from time to time to publish separate articles on different branches of alternating-current work, and on such alternating-current machinery as the stationary engineer has to do with. These articles just concluded will, therefore, form an introduction for the study of the applications of alternating currents.

BOILERS AND SMOKE TROUBLES

R. T. STROHM

COMPARATIVELY few firemen are familiar with the nature of the chemical actions which take place in the boiler furnace during the process of combustion, and while such knowledge is not absolutely necessary in order to avoid the formation of smoke, it is undoubtedly a fact that its possession is a great aid in the attainment of desirable results.

It may happen that the fireman is thoroughly posted on the theory of combustion and carefully applies his knowledge to his work, and yet fails to obtain the greatest possible heating value of the coal used. When this is true it indicates that something besides the firing is wrong and an investigation should be promptly made.

Efficiency of steam production and economy in the use of fuel are closely related, and where one exists, there exists the other, while both hinge upon the question of perfect combustion. Where there is smoke, there is not the most perfect combustion, and as a result, there is less total efficiency. Should chemical analysis of the flue gases, together with tests of the boiler, show that sufficient air was being introduced into the furnace, and yet there remained trouble from smoke, it would be necessary to look further than the combustion to determine the cause.

A faulty design of boiler or of furnace may so affect the disposition of the gaseous products of combustion as to make the prevention of smoke an impossibility without total reconstruction or rearrangement of the heating surfaces.

Such has been the experience with more than one make of boiler, and in nearly every case the failure is due wholly to a poor placing of the heating surface. The capacity of a boiler to absorb heat, and hence to produce steam, is dependent upon the amount of heating surface it contains. Designers, therefore, aim to expose as much surface as possible to the hot gases. There, apparently, their thought and care ends. Having decided upon the shape and the amount of heating surface, they place a furnace beneath, and the result is an apparatus which will generate steam more or less econom-

ically, and so obtains the name of steam boiler.

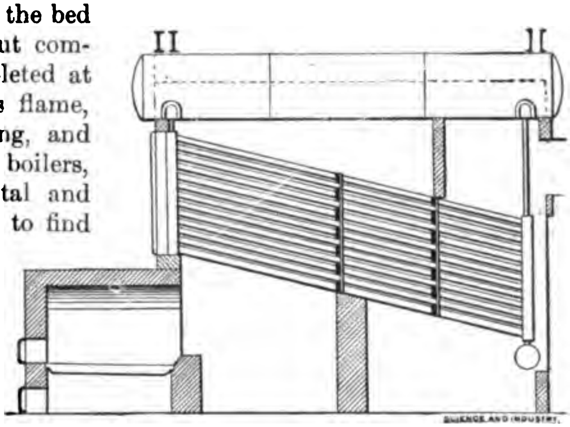
It is this random and apparently unstudied placing of the heating surface in steam boilers which has to do with the smoke trouble, to a great extent. The fault commonly lies in getting the tubes or plates too close to the flames.

To support combustion, which means the union of carbon and oxygen, it is necessary to maintain a temperature of at least 800° F. At temperatures lower than this there can be no burning of the coal. It is common in furnaces to have a temperature of 3,000° F. and over, just above the bed of live coals on the grate. But combustion is by no means completed at this point. Wherever there is flame, there combustion is continuing, and among the tubes of water-tube boilers, and in the tubes of horizontal and vertical boilers, it is common to find flames, extending all the way from the grates. But where this is the case, there is also a certain amount of smoke.

Let us take the case of a boiler carrying steam at 120 pounds pressure. The temperature of this steam is 350° F. Assuming that the tubes and plates are kept moderately free from deposits of any sort, the temperature of the fire side of the shell or tubes is less than 400° F. Now, the gases at a temperature of 3,000° F., coming into contact with the tubes, are so chilled that their temperature falls below 800° F. After that, there can be no combustion, and any carbon which may remain unconsumed, will be carried along in the current of gases and be deposited, either on the tubes and plates as soot, or else carried up and out of the chimney as smoke.

In other words, the only way to secure complete freedom from smoke is to obtain perfect combustion. As has been stated, combustion is not completed just above the grates. In many cases it is continued all the way through the combustion chamber and into the tubes. So that the crowding of water tubes close to the fire, or the placing of plates near it, is a remarkably poor arrangement, and is productive of all kinds of smoke troubles.

Where anthracite coal is used, there is not the same liability to have dense black smoke that there is in cases where soft coal is burned. Hard coal contains a very small percentage of



volatile matter, or hydrocarbon, while soft coal contains much. The first has a short flame, and the latter a very long one. So that where anthracite coal is used, the grates may be placed closer to the heating surface than would be advisable with soft coal as a fuel.

The main point, then, is to provide a chamber of sufficient volume, in which combustion may be completed before the gases shall be allowed to touch the heating surface. If this is done, no smoke can be formed, due to the cooling effect of the metal plates, and heating surface of sufficient area may be used to take up as much

heat from the gases as is desired.

In every boiler from which smokeless results have been obtained, it will be found that this idea has been carried out. The size of this combustion chamber will depend wholly upon the kind of fuel and the extent of grate surface. A rich hydrocarbon fuel will necessitate a considerably larger space than a fuel not so rich in volatile matter. Besides, there must also be provision for the admission of air into the combustion chamber, so that there may be sufficient oxygen mingled with the gases to insure their complete combustion. Further still, the combustion must be complete before the gases strike any part of the cooler heating surface.

All these principles are embodied in the boiler with a separate furnace, such as the one shown in the illustration. Here the furnace proper is built external to the boiler proper. It is of heavy firebrick walls, with an arch of the same material over the grates. Firebrick, being both refractory and a poor conductor of heat, is admirably adapted for use in this place, as it keeps the furnace temperature at a high point, and so promotes regular combustion.

Beyond the furnace is a large chamber into which the gases pass and are mingled with air. This chamber is also of firebrick, and in it the combustion is completed. The hot gases are then passed by a devious path over the heating surfaces of the boiler.

This will serve to show that the design of a good boiler is something more than a calculation of heating surface and a proportioning of parts. It begins with a study of the fuel to be used, and the first points to be fixed upon are the size and the shape of the firebox and combustion chamber. After that, any convenient arrangement of the heating surface will answer.

FRICTION—II

H. ROLFE

VARYING CONDITIONS IN RESEARCH WORK — RELATION BETWEEN SPEED AND FRICTION. FRICTIONAL WORK AND HEATING—COMPUTING THE LOST WORK IN A BEARING

Conditions of Experimenting.—The varying results arrived at by investigators into the matter of friction are due to the different conditions obtaining at the time. Putting aside the different kinds of material employed, we would remark that some have experimented with dry surfaces, which in some cases were actually clean and in others were more or less contaminated; other experimenters have dealt with lubricated surfaces, varying from those merely greasy ("unctuous" as the old phrase put it) up through the different states of siphon, pad, and bath lubrication. Then again, the speeds varied from very slow to very high ones; in fact from $\frac{1}{32}$ of an inch per second up to 100 feet per second. So also with the pressures; these have ranged from 2 or 3 pounds per square inch up to the point of seizure, which may run from 50 pounds per square inch in the case of dry surfaces up to 500 or 600 pounds per inch with ordinary lubrication. In special cases, such as with forced lubrication or with water circulating through the interior of the journal, excessive pressures have been carried. On one occasion 9,000 pounds per square inch was carried for several hours at a rubbing speed of over 200 feet per minute, the viscosity of the oil being maintained by the

expedient of keeping the temperature down artificially by means of water circulation.

Here we refer, be it remembered, to steady "dead" loads. The working conditions of much of our machinery differ therefrom, notably in locomotives, where the load is neither steady, constant in direction, nor "dead." Thus, the load carried on a driving journal is from 250 to 300 pounds per square inch; on a main crankpin 1,500 to 1,800; and on a wristpin 4,000 to 5,000; and these, be it remembered, are only the computable stresses, dead weight in the first case, and steam stresses in the second and third. They are moreover likely to be exceeded at any moment, due to steam in first case and inertia effects in all three.

Again, there is the matter of temperature, a very important item; experiments have been carried out in which the temperature was initially very different in the several cases; further, in some instances it was allowed to mount up (the heat-conducting ability varying greatly according to the oil and metals used), and in others it was carried away by circulating cool water through the bearing. No general values of the coefficient of friction can therefore be given for any stated combination of materials, although many books profess to do this, in which respect they are certainly misleading.

Speed and Friction.—So long as the pressures are not excessive (having regard to the nature of the materials), the intensity of the friction when at rest does not differ materially from that at low speed, in the case of dry surfaces or of imperfectly lubricated ones. When, however, the pressures are high or the materials are of a soft nature (as lead, wood, etc.), the parts will embed themselves into each other when standing, and so oppose greater resistance to subsequent motion; whereas, when once in motion the bodies do not have time to bring about this condition, sliding over one another, in fact, with less effort.

One investigator, experimenting with leather belts on cast-iron pulleys, found that with clean surfaces and light pressures, the friction at very low speeds was greater than the friction at rest. As the speed increased, the friction gradually increased and then decreased again.

We have already alluded to the influence of speed on the maintenance of the lubrication and hence on the friction. Be it remarked that at low speed, the efficiency of the lubricating system employed is of less effect than at high speed. Prof. Goodman, experimenting with heavy unit pressures, found the results much the same whether he used the bath, pad, or siphon method of lubrication. He found that the smaller the part of the journal circumference embraced by the bearing, the less was the friction. Table I shows one of these sets of results.

TABLE I

System of Lubrication	Length of Chord of Bearing Surface				
	Inch 2.0	Inch 1.75	Inch 1.5	Inch 1.0	Inch 0.5
	Coefficient of Friction				
Oil Bath	.92	.70	.64	.48	.47
Saturated Pad	1.13	.92	.72	.48	.46
Oily Pad	1.87	1.25	.94	.57	.51

The opinion formerly prevalent that there is an abrupt and sudden change in the coefficient of friction when the surfaces come to rest relative to each other, is no longer held, experiment showing that although the static and kinetic coefficients may be widely different, yet the change from one to

the other is really only gradual; that is, observations made while the velocity was diminishing very gradually showed that the increase of the coefficient also merged gradually into its static value. Evidently, in order to deal with this

TABLE II

Rubbing Speed in Feet per Minute	Relative Values of Coefficient of Friction
.00058	0.37
.00225	0.51
.00500	0.73
.01100	1.00
6.0	1.00
22.6	0.60
50.4	0.46
110.0	0.29

point satisfactorily, observations had to be made at very low speeds, and as a matter of fact, this was done, the friction being noted at speeds as low as $\frac{1}{400}$ of an inch per second. It was found that the coefficient for brass was .146 for all speeds between $\frac{1}{400}$ inch and $\frac{1}{24}$ inch per second, while for steel on steel, the coefficient increased from .119 at $\frac{1}{400}$ inch per second to .13 at $\frac{1}{220}$ inch per second. Table II shows how the friction varied with the speed, first increasing and then decreasing; the experiments were with a 1-inch steel shaft in a cast-iron bearing. Many experimenters with lubricated bearings seem to have established the fact that at very low speeds the coefficient is greater than when just moving from rest, the coefficient, as a rule, attaining its maximum at a speed of about 2 feet per minute. Altering the pressure between the surfaces, however, alters the speed at which the maximum coefficient occurs. Table III, embodying some results of Prof. Goodman's experiments with journal bearings, shows how the coefficient changes in value as the speed varies; the system of lubrication employed was very efficient. With only 50 pounds per square inch on the bearing, the coefficient gradually increases with the speed. With 75 pounds the friction is high when starting up (due to the oil having squeezed out); here also the friction mounts steadily with the pressure. With 150 pounds, the friction decreases until a certain speed is reached, after which it increases again. Here it will be noticed that with heavy loads, the friction is greatest at low speeds, this effect being less noticeable with light pressures. The reason is that a certain degree of speed is necessary to ensure the proper maintenance of a film. With regard to unlubricated surfaces under high pressures, the coefficient of friction diminishes as the speed increases. We have alluded in a former article to the Westinghouse railroad experiments conducted more than 20 years ago. Tables IV and V show the results then determined.

The above results were all determined experimentally with the exception of those for zero speed, which were calculated. It will be noticed

TABLE III

Rubbing Speed (F. P. M.)	Coefficient of Friction under a Pressure of		
	50 lb. per Sq. In.	75 lb. per Sq. In.	150 lb. per Sq. In.
5		.0025	.1145
10	.0009	.0007	.0250
15	.0012	.0008	.0051
20	.0014	.0009	.0034
25	.0017	.0011	.0027
30	.0021	.0013	.0023
40	.0026	.0016	.0019
50	.0032	.0018	.0017
70	.0042	.0024	.0017
90	.0053	.0030	.0020
110	.0064	.0036	.0024
130	.0075	.0042	.0029
150	.0086	.0048	.0035
170	.0096	.0054	.0041
190	.0106	.0060	.0047

how the friction decreases with the speed, and also, in Table IV, with the duration of contact. The friction is much greater in the case of the brake-block on the wheel than of the wheel on the rail; one would not expect this, bear-

ing in mind that in the first case one of the surfaces is cast iron while in the second, both are steel. The explanation possibly is that the sliding wheel is continually moving over a more or less dirty rail and so meets a renewal of contaminated surface all the time, whereas the small amount of contamination carried around to the brake block by the revolving wheel is soon rubbed away and two clean surfaces remain in contact. Another possible partial explanation of the reduction of coefficient with duration of contact in the latter case is that the abraded particles of cast iron act as a dry lubricant, filling up the interstices of the contact surfaces.

Frictional Work and Heating.—Whenever work is performed, heat is produced, and the equivalent of the work done must be apparent in some shape or other. Energy is indestructible and although it may seem in a certain case to be wasted, yet it is only transformed into another guise. Thus, mechanical energy may be absorbed in lifting against gravity, or it may produce chemical or electrical energy or it may generate heat. If we lift a

TABLE IV

BRAKE-SHOE FRICTION

Average Speed. Miles Per Hour	Coefficient of Friction (at the Intervals Noted) Between Cast-Iron Brake Shoes and Steel Tires		
	First 3 Seconds	From 5th to 7th Second	From 12th to 16th Second
0	.408 Cal.	.285 Cal.	.237 Cal.
5	.360		
10	.320	.209	
20	.205	.175	.128
30	.184	.111	.098
40	.134	.100	.080
50	.100	.070	.056
60	.062	.054	.048

weight, we have something to show for our efforts, and the weight if released will fall down and draw up another one of practically the same mass. If we drag the body along the ground, what has then become of our energy? The weight has gained nothing—no advantage of condition; we have not put it into any position by virtue of which it can do work; in other words, have

TABLE V

WHEEL AND RAIL FRICTION

Average Speed. Miles Per Hour	Coefficient of Friction—Steel Tires and Rails
	During First 3 Seconds
0	.141 Cal.
10	.110
15	.087
25	.080
35	.051
45	.047
50	.040

not endowed it with *potential* energy, as when we lifted it to a height. Our work has been expended in overcoming the frictional resistance to sliding and has been all turned into heat. The heat is readily dissipated and is not susceptible to the touch; the schoolboy trick of heating a metal button by rubbing it on his coat sleeve is an exactly similar, only more pronounced, case to the above and one that makes tangibly evident the truth of the statement; and we might further allude to the time-worn yarn of generating heat, and eventually a light, by rubbing two pieces of dry wood together. The point is simply this: work cannot be wasted; there must always be something to show for it. An engine drives a dynamo, we will say; some of the power put into the latter is lost in heating up the core, etc. But allowing for all heat and electrical losses, the output is still less than the input. The remainder has been absorbed in the bearings; it has been expended in overcoming the friction—in performing frictional work, in fact; but there will be something to show for it, namely, increased temperature in the bearings. In short, as soon as there is

experienced any resistance in rotating a journal, there at once commences the generation of heat. If the lubrication is good, the friction will be that of oil on oil, and the amount of heat generated will be small; if it can be dissipated quickly enough from the bearing, well and good. If not, it will accumulate and raise the metal to a black heat and even hotter, melting the babbit and eventually welding the parts together if both are wrought iron or steel, as has sometimes been experienced when this combination has been tried. If we could accurately measure all the heat generated in a bearing and note the work expended in rotating it (we assume no belts or other resistances), the two would correspond; the thermal units of heat generated per minute would equal $\frac{1}{778}$ of the foot-pounds of work done per minute. The rate at which heat can be conducted and radiated away from a bearing depends on conditions. If the oil and the babbit have good heat-conducting qualities and the bearing is running in a cool and changing atmosphere (a locomotive exemplifies the latter point), the rise of temperature will be less than if the reverse conditions obtained.

The frictional work expended in a bearing may be estimated as follows: Let w denote the total load on the bearing in pounds; let d denote the diameter of the bearing in inches; let n denote the revolutions per minute; let P denote the coefficient of friction.

The resistance to rotation acts at the surface of the journal, which moves—relatively to the surface of the bearing—through a distance πd inches in each revolution. The frictional resistance that has to be overcome is a certain proportion of the load, namely, Pw. Hence, the work absorbed in overcoming the frictional resistance to rotation is, in one revolution, $\frac{\pi d P w}{12}$ foot-pounds. (We divide by 12, because the diameter is in inches, this being the unit employed for journals even when they are more than 1 foot in diameter).

In 1 minute the lost work is $\frac{n \pi d P w}{12}$ foot-pounds, and we can express this in equivalent horsepower by dividing by 33,000; or, the H. P. absorbed or lost $= \frac{n d P w}{126,100}$. If an 8-inch journal carries a load of 22,000 pounds, and is running at the rate of 250 revolutions per minute, and the coefficient is .02, the H. P. lost is

$$\frac{250 \times 8 \times .02 \times 22,000}{126,100} = 7.$$

If the bearing is 9 inches long, the unit pressure (reckoned on the projected area) is $\frac{22,000}{9 \times 8} = 305$ lb. per sq. in. For the bearing to be satisfactory, the heat must be carried away as quickly as it is generated; the facility with which this heat is conducted away from the journal and bearing varies not only with the nature of the oil and metals, but also with the atmospheric surroundings—already explained in a former article.

In the case of a locomotive (of which practice the above example is an illustration) the conditions are very favorable, especially for revolving parts such as crankpins. We can now ascertain how this journal stands. One British thermal unit is the amount of heat generated by the expenditure of 778 foot-pounds of work—supposing all the work to be spent in generating heat.

This quantity, 778 foot-pounds, is called the mechanical equivalent of heat. In the case given above, the heat units generated per minute are found

by dividing the foot-pounds of frictional work performed in that time by 778 B. T. U. or $\frac{n \pi d P w}{12 \times 778} = 296.$

The area of the bearing is $8 \times 9 = 72$ sq. in., and therefore, in order to prevent the temperature rising indefinitely, each square inch of bearing must convey away 4 heat units each minute.

The items of pressures and speeds, and a consideration of how and why they differ in different lines of machinery, will be more fully treated in a subsequent article.

HINTS FOR THE DYNAMO TENDER

AN article, by Mr. R. Max Eaton, with the above title appeared in Electricity some time ago. It contained such excellent advice and information for those not over familiar with the care of dynamos that we reprint it here with their permission.

"An attendant for electrical machinery should understand the elementary principles of electricity, the units of measurement and how to apply them, the laws and phenomena of induction, the principle involved in the different styles of dynamos, and have an intelligent knowledge of the electrical science in all its branches.

"The following consists of suggestions covering some of the more important features with which a dynamo attendant should be familiar.

"*Clealiness* I place first in the list, for I believe it is the most important feature in the operation of a central station. What a story the appearance of a dynamo room and the machines tell to the close observer.

"It is unnecessary to comment, to any length, on this point, because the fact has been so well established, that the greatest enemy to the successful operation of electrical machinery is dirt. The fact that a generator may be nicely painted and well finished does not increase its efficiency, but it certainly will act as an incentive for the operator to keep it clean and of a good appearance, and that of itself is of considerable importance.

"Machines should always be cleaned immediately after they are shut down. Better results can be accomplished then than if allowed to cool, as it is then much more difficult to remove the oil and grit."

The dust and dirt in the inaccessible parts of a machine are most easily and surely removed by means of an air blast. The air blast is now used for this purpose, especially in stations having a number of machines to keep clean. The air is supplied through a flexible rubber hose, a small portable motor being used to operate the air pump.

"If convenient a suitable canvas cover should be provided and placed over a machine after it has been cleaned to prevent dust settling on it.

"*Installation.*—The location selected for the placing of a dynamo should be cool and dry and in such a position if possible that the machine will be easily accessible on all sides. Do not place it in such a way that it would be impossible to remove the armature without moving the entire machine. This is a mistake that is often thoughtlessly made. In placing dynamos of considerable size, a foundation of brick or stone should be provided, constructed if possible separate from the walls of the building. In any case a level and firm foundation ought to be provided.

"In placing the parts of a machine together and mounting the apparatus the greatest posible care should be

taken to thoroughly clean each part and all connections. The shaft and bearings must be thoroughly wiped before putting the armature in place.

"*Belting.*—The kind of belting to be used is to a great extent a matter of opinion. The standard light-weight, double-leather belt is, however, applicable in most cases and as a general rule satisfactory. Use endless belts by all means as it is not advisable to operate a high-speed machine of any description by laced belts.

"In estimating the size of belt required to do a certain amount of work, it may be taken as a guide that a single belt will transmit approximately 1 H. P. for each inch in width when running at a speed of 1,000 feet per minute. If the speed is greater, the power transmitted will be correspondingly increased, and if it be less the power will be correspondingly decreased.

"Always operate a leather belt with the smooth surface next the pulleys and the slack (running) side on top if possible.

"On new belts an allowance for stretching should be made, in placing the machine, of $\frac{1}{4}$ of an inch to the foot in its length. In calculating for speed it is advisable to allow 1 per cent. for slipping, as it is certain to occur to this extent when doing work. Endless belts can be made without the use of rivets; use specially prepared cement for splicing and avoid the use of rivets.

"*Directions for Starting.*—Make a careful examination of the entire machine to see if the connections are all right and also to make sure that no tools have been left carelessly lying about. This sort of an examination becomes a second nature to attendants who have been operating machines for some time, and they unconsciously perform this very important proceeding without thinking that they are doing it. Note if the brushes are all set and have the proper tension. It is often customary to bring dynamos to their full speed before lowering the brushes into contact with the commutator. This is not at all necessary, in fact it is much better to place and set all the brushes before starting at all unless there is some danger of the machine being turned backwards, which would injure copper brushes. The main switch connecting a dynamo into the circuit should not be thrown in until the dynamo is "built up," that is, operating at the required voltage indicated by a voltmeter or pilot lamp; however, this does not apply if a dynamo is operating an independent circuit, for then it does no harm to have the circuit on and allow it to build up with the machine. Never throw a heavy load on a generator suddenly if it can possibly be avoided, but gradually build up its load by means of circuit switches, or if operating in multiple with other machines, the shifting of the load should be done gradually.

"*Directions for Running.*—If a machine is new and is being run for the first time, special attention should be paid to it for awhile, and for a short time it is advisable to run it at less than full load if at all convenient to do so. Fresh oil should be added to the bearings quite often and the old run off. Be on the alert for excessive heating of the bearings, field coils, or armature, and if any is discovered no time should be lost in finding the cause and applying a remedy.

"Special care should be taken in handling generators which are operating at an E. M. F. of 500 volts or over. 'Keep one hand in your pocket' is an old saying; however, this is not always convenient to do, but it serves to

illustrate the impression we wish to convey.

"Do not overload a dynamo, as this is the direct cause of probably as much trouble as any other individual thing.

"Keep all iron or steel tools away as they might be drawn into the machine by the magnetism and be the cause of entirely ruining it. Copper or brass oil cans should be used for the same reason.

"*Directions for Stopping.*—If a generator is operating in parallel with others gradually remove the load until its ammeter indicates little or no current, then open the switch. Under no circumstances allow the speed to be lowered or the magnetism weakened (except enough to regulate the E. M. F.) before disconnecting. If this were done, the machine would probably run as a motor, taking its current from the main circuit, which might cause no end of damage.

"If a machine is operating alone on a circuit, gradually decrease the speed and allow it to stop without touching either the brushes or switches. Do not switch out a dynamo at full or partial load except in a case of emergency.

"Never lift a brush while a dynamo is generating current, except when there are other brushes on the same side to remain in contact.

"As soon as a dynamo is 'shut down' clean it thoroughly and raise the brushes, taking care to wipe all the copper dust from the commutator, brushes, and brush holders, after which it should be covered, if a cover is provided.

"*Sparking at Brushes.*—The causes resulting in this trouble are very different in different types of machines. Most all-arc dynamos spark considerable while operating, but that is not objectionable as they are designed to stand it.

"A few of the more common causes of this trouble in direct-current multiple machines are brushes not set at the neutral point, current overload, rough commutator, open coil in armature, short-circuited coil, leak from coil to frame, weak or uneven magnetism, bad brushes or unnecessary vibration of the machine.

"If the sparking occurs from the brushes not being set at the neutral point it can be readily overcome by shifting the rocker-arm either backwards or forwards until the neutral or non-sparking point is found.

"An overload will produce sparking as probably the capacity of the commutator and brushes may not be sufficient, and in this case there is no remedy except to reduce the load.

"It is not a difficult matter to keep a commutator which has no inherent defects, in good condition if attended to properly from the start; but if allowed to get rough and full of ridges it takes considerable care and work to bring it right. It is very damaging to a machine to run it with the commutator in bad condition.

"An open coil can be detected by a spark that will appear to travel almost around the commutator. The defective coil can sometimes be found by noticing which bar is most damaged by the spark. If there is not time to repair it the dynamo may be operated for a short while without damage by connecting the two bars together between which the open coil exists. An open very seldom occurs in the coil itself but more generally where the wire is connected to the commutator bar. This is easily found and remedied.

"A short-circuited coil will heat much more than any of the others and is very liable to burn out entirely. It may be detected by holding a piece of iron between the pole pieces and in

such a way that it will be influenced by the magnetism, and if the pull varies suddenly at a point in each revolution it demonstrates that a defective coil exists. Of course this test must be made while the machine is generating current.

"A leak from the windings to the frame may be detected by testing with a magneto bell or by the use of a battery and telephone receiver.

"Weak or uneven magnetism will cause sparking and also result in the dynamo not generating its full E. M. F. when running at the required speed.

"The brushes should set on the commutator in such a way that the intended contact surface shall all be in contact, and also they should have no ragged edges but ought to be kept properly trimmed.

"It may be said that excessive heat exists if the armature or field coils get too hot to keep the hand on for a short time."

CLEARANCE—I

The Term as Applied to Engine Cylinders Involves Two Distinct Matters—Considerations That Render Piston Clearance Necessary—With Given Amount of Wear, the Alteration of Clearance Depends on Design of Parts

THE term "clearance" as used in connection with steam engineering has two distinct meanings, or in other words, is applied indifferently to two separate items, although, as will be herein shown, one of them always includes the other. The term in its dual meaning is often very loosely used, both by students making inquiries and also, we may add, by certain writers whose knowledge of the subject is unsubstantial because only "bookish," such knowledge consisting therefore, as it must ever do in such circumstances, of a series of bald and undigested facts. We shall here try to show what the several reasons really are for employing clearances. While referring to locomotive work, for sake of illustration, our remarks apply in principle to all classes of engine work.

If a steam engine could be constructed with mathematical accuracy, and were to remain in that condition, we should not need to make the cylinder any longer than the thickness of piston plus the length of its stroke, or twice the length of crank. (At least, the stroke is equal to twice the crank, generally speaking, although in all American locomotives it is, as a matter of fact, slightly in excess of this. The discrepancy is very slight and is due to the cylinder axis being 2 or 3 inches above the center of the drivers. We merely mention this in passing.) There are many contingencies that have to be taken into account, however, both as affecting the initial accuracy of the machine, and also the subsequent impairment of same. As regards the *first item:* in standard engine work, where accurate spacing is secured by the use of jig and templet, and accurate sizes by making all parts to gauge, there is not much room for variation. Still, if all the minute errors of machining and subsequent fitting were cumulative, the result might be of moment, if on their joint effect depended the contact or the clearance of some pair of parts, such as the cylinder head and piston for example. And further, all the sur-

faces that affect this matter of clearance are not machined; thus, the faces of the piston and also of the cylinder heads are left black, and although the machining may be done accurately enough with reference to these faces as a whole, yet local swellings might be present in greater or less degree.

Where the piston rod has a bottoming fit in the crosshead and a shoulder fit on the piston, the over-all length of connected parts will never vary from the original, nor the latter from standard, if the parts are machined to right length and the tapers are not "botched" to begin with. But where the fit is made wholly on the taper, so to speak, the over-all length is liable to be left either a trifle long or short, as the case may be, although this is less likely when ground fits are employed—done in lathe—than when the fitting is done in the vise. If the turner should get his rod ends too small, or the crosshead or piston bored out too large, the distance from the back face of piston to the crosshead pin will be short, and the back cylinder head will be struck at each stroke. If the reverse obtains, and the machinist shirks the necessary filing or the remedying of same in lathe, the over-all length will be full, and the piston will strike the front cover. Of course, with careful gaugers (when such are employed) any considerable deviations of the above nature would not pass. And in repair work, it would not really matter so much, as the length of main rod would be taken off to suit, after all the concerned parts were in place—the driving boxes, the guides and cylinders, together with the pistons, piston rods, and crossheads. And any such fault as above alluded to (undue fullness on either side of the piston or on either cylinder head) would here be taken care of by the practice of bumping-up at each end, when preparing to find the rod length. We are talking, however, of new work, where the main rods are perhaps made and finished weeks before the engines are erected. They are made, therefore, to the length shown on the drawing. After this has been done, to alter the length by lining up or by filing back of brass (according to the design) would be a bad piece of work. Here, then, we have *one* reason why piston clearance is given; it provides for any slight discrepancies such as the above. In fact, it is scarcely necessary to labor the point that where a certain over-all distance includes several parts and many fitted surfaces, the natural tendency of the practical designer would be to make an allowance for possible discrepancies and provide "clearance," even in the case of new work and good workmanship. In so acting, he is merely trying to secure the same certainty of freedom of working, as he is of strength when he makes parts four or five times as strong as the known and *computable* stresses call for.

So much then for the necessity of clearance in the case of an engine that is assumed not to alter its original condition. When we consider the second item, we shall see yet stronger reasons for this clearance, for here the element of wear comes in, and also that of repairs and renewals. First consider the effect of wear. This occurs in both ends of the main rod but about six times as fast in the back as in the front. It also takes place in the axle journal, the brass, the box, and also in the shoes and pedestals. As regards play or knock in the rod, the effect of it in the two ends is additive and endangers both heads when drifting, although compression may keep them intact when running under steam. The play in the other parts named will also tend to make the

piston knock the cylinder heads; and there is no provision for taking up the wear in any place but the pedestals, and then, in nearly all cases, it is not done symmetrically (i. e., to maintain the original centers) but simply crowds all the slack to one side of the box, throwing the piston towards the one end of the cylinder.

We thus see that the effect of wear is to decrease the clearance between the piston and the cylinder head; whether or not the taking-up of this play overcomes the evil and restores the initial conditions depends, as just partially expressed, on the design of the parts. Now what we require to do is to not only maintain the main rod and other bearings without any play (except such as practical considerations call for) but also to preserve the right distance between centers, and these two conditions by no means harmonize as to their maintenance. As regards the main rod: if the wear *was* equal at each end, and the key (sometimes a wedge and bolt are used) were in each case on the same side of its own pin, then on keying up the slack, the length would remain intact. But whereas the wristpin brasses are always tightened up from the back side, those of the crankpin are not. If the back end is of the butt-and-strap type, the key is always in front; if a solid or box end the key is sometimes in front and sometimes behind. If a forked end, the key is usually in front. Now, whatever the design of rod, it is possible, of course, to take up the play without altering the centers, by putting a liner in on the non-key (call it the "plain") side of the brass. This, however, is seldom done until the key is driven right down; then the repairman will line up on the plain side to bring the brass central (using the oil hole as a guide, for that will not have been opened out when letting together, as will the other half) and also put a liner next the key to bring the latter back to its original height. The engineman cannot be expected to do any lining up; he simply goes on driving the key down as long as brute force will close the brasses in any more. Neither does the repairman trouble about lining up until the key is right down, and then he suits his convenience in apportioning the liners, as a rule shirking the trouble of pinching the rod back to halve the liner between the two brasses, as he ought to do. He simply leaves the clearance to take care of this, or perhaps does not give the matter a thought. The taper on the keys varies, maybe from 1 in 16 to 1 in 20. Assuming the former and a length of drive of $2\frac{1}{2}$ inches in front end and 3 inches at back, the fact of both keys being down would mean an alteration in rod length of $\frac{1}{16}$ in. $\times\ 5\frac{1}{2}$ or about one-third of an inch. This would be so if keying-up drove the brasses away from each other; the actual amount would really be less than above, however, because the front key would not drive down in anything like the time the back one would and besides, some of the wear as represented by the descent of key has taken place between brass and liner, liner and key, and key and rod, all of which does not alter the centers; these amounts are but a small proportion of the whole, however. Now this gross amount acts to either shorten or lengthen the rod, according to the design. While discussing the effect that keying-up has on the centers, we would allude to the old-fashioned style of having straps held on by gib and cotter (i. e., key) only; no bolts and no separate key for the brass. The brass drew up against the butt end of rod, and driving the key down short-

ened the rod, this being the case for each end. This design is never seen on back end now, and but seldom on front ends either, although it is much less objectionable there. There is yet another point that deserves mention: It is a common practice (and in our opinion a bad one) to key piston rods into crossheads having a through hole, i. e., with the rod hole running clear through. If, in addition, the taper is small (only 1 in 24, say) and the rod does not draw up on a shoulder, then the first rough shock (as water in cylinder, sanding with open throttle while slipping, etc.) will drive the rod up another $\frac{1}{8}$ inch or so. Another point for consideration is the wear of the boxes in the pedestals. This is taken up by the wedges, which are generally at the back end only, and their tendency is to bring the cylinder and main axle nearer together and so decrease the front-end clearance—having the same effect as lengthening the main rod, in fact. The main rod is lengthened by taking up the wear, this being due to having the keys in the main rod *between* the pins (that is, the front-end key is behind the wristpin, and the back-end key is in front of the main crankpin), this being the almost universal practice. Thus, the two effects —wear of pedestals, etc., and the wear of the rod brasses—aggravate matters, by operating together. The other cause, namely, the displacement of the piston or crosshead relative to the piston rod, acts to neutralize the other two, when it *does* take place; although, as a matter of fact, any such contingency would as likely as not occur on an early trip, before any wear of parts had taken place at all.

We spoke just now about driving the key right down before lining up at all; we will make our position clear thereon. We do not suggest that every time a brass is reduced, an equivalent liner should be put in, because this would simply render useless the driving length of the key. This extra length (standing up above the strap) is intended as a convenience. A brass is often renewed in haste, when there is no time for fitting in liners, a thing that always requires proper attention; the length of key then proves of service. Our point, however, is that it is wrong to go on setting up the key repeatedly and putting all the liners in the same place, i. e, on the same side of the brass always. On dusty roads, where the wear is rapid, the clearance may thereby soon be dangerously decreased. Of course, the *careful* machinist will watch the clearance marks on the guides, uncoupling and bumping-up if in doubt. To make this comparison, however, involves pinching the engine around, and time or trouble may cause him to shirk this. Therefore, to be on the safe side, he should notice whether there is an undue amount of liner on the key-brass, having regard to the amount it has worn (he will know the original thickness if standard work, and approximately so if not), and then see how the liner on the other half brass measures up. If much discrepancy, he will divide up so as to bring the bore central with oil hole—thus restoring the rod to its original length, so far as that end is concerned.

Sometimes a brass will be found cracked or broken, say the plain half. If it is much worn, and has been lined up to suit, regard should be had to this fact when replacing the brass. Suppose the old half has worn down $\frac{1}{4}$ inch, and the one put in to replace it is practically a new one; then if the liner found on the broken brass were transferred to the fresh brass, the rod length would be altered nearly $\frac{1}{4}$ inch, or whatever the difference in

the crown thicknesses happened to be. The proper procedure would be to line up the fresh half until the thickness from the face of bore to back of liner was equal to the standard crown thickness for that rod, altering the liner on the key-brass until the key was up to its original height. All this may seem rudimentary and obvious to the reader who has done much rod work (repairs), but it is meant principally for those who have not, and is intended merely to show what are actually the causes at work that constitute the necessity of piston clearance. The hints given will be of service to the novice going on rod work for the first time; and, further, those who are supposed to be posted in this work do not always do what they should. The presence of ample clearance—at the right end—has without any doubt often compensated for a man's hurried and careless work and prevented a smash-up.

(To be Continued.)

DRAFTING

WILLIAM BURLINGHAM

DOUBTLESS many of the readers of this magazine have in contemplation the profession of draftsman as a preliminary to the better paid duties of the professional engineer.

It is for these men that this paper is written, embodying as it does a brief description of what to do and what to avoid in order to make a success in that line.

In this country, drafting, as a profession is considered but a stepping stone to something better, and it is unique in the respect that it requires practically all the application and learning that is necessary to the full fledged profession of engineer, with the exception of the executive ability.

In foreign countries, drafting is considered in itself a profession, and a draftsman remains a draftsman to the end of his days. Those who have ambition and desire to better themselves come to this country and become a very desirable class of citizens.

In our restlessness we are constantly striving for something better, and in consequence, the ranks of our superintendents, managers, and owners are very largely recruited from the ranks of the draftsmen.

It is often said in the machine shop, that the drawing room is impractical and theoretical. On the contrary, it is both theoretical and practical; and I desire no better proofs of the results of intelligent designing than the magnificent ships and engines that are sailing over the two oceans, or the almost human machines that are scattered in every city in the country—or, one might say, in the world.

There is hardly a designer who has not had some experience in the shop, and although not able, probably, to go into the shop and finish a piece of work with the man at the bench, it is an even chance that they could indicate the best and cheapest way of doing it. I am now speaking of men of five or six years' experience who have worked in different shops and absorbed their different ways of doing work.

A draftsman has the advantage over the machinist in that he is brought into contact with all classes of work and consequently his brain has been lifted out of a narrow groove and taught to look on all sides of a subject before deciding on the best way, and I am free to confess that the elder machinist very often sees only one way and that very thoroughly.

Far be it from me to say one word that would detract from the ancient and honorable craft of machinists. I only desire to place the designer in the position that he rightly deserves, by hard work and persistent study and help him to avoid being crushed between the machinists' scorn of his so-called impracticability and the employers' desire to get good work in one-quarter the time that should be expended upon it.

Many bright men in the machinist trade have not had the opportunities that have been granted the average draftsman. But, in the present time there is hardly an excuse for not being well grounded in the studies necessary for the successful engineer.

What with the correspondence schools and their low cost of instruction, the evening schools in every city of any importance, and the technical universities, and the manual training schools, I can see no reason why any one with the natural ability cannot raise himself to a position commanding a good salary.

It is only of late years that the employers have begun to realize that the prosperity of a plant depends in a great measure upon the drawing room. Thousands of dollars worth of mistakes could be easily made and it is to the credit of the draftsmen that the employers seldom think of such a thing as a bad mistake coming from the designing room.

Suppose it was the other way and the draftsmen did not keep up with the latest designs and improvements in engineering, the effect would be quickly seen, in the decreased sales, and consequent decrease in the income. It is to their credit, that as a whole they do their best work cheerfully and are as interested in each design as if it were their own. They follow the construction of it through the works and, for instance, if it is a ship or engine that has been constructed, they have an interest in that ship or engine until she is wrecked or lost; and without doubt can tell you what she is doing many years after her construction.

It would be interesting to jot down the wealth and comfort producing ideas that have crystallized in the minds of draftsmen, or engineers that have graduated from their ranks. The people of this country owe a large debt of gratitude to the mechanical talent, whether of designer or machinist, for the work they have done for them.

It has been said recently that this century would be ruled by the engineer. It would seem as if this must be so. The majority of investments today are in companies or corporations that are depending upon engineering ability for their commercial success.

To wit: Manufacturers, railroads, sugar machinery, pumping plants for oil, canning machines for food, and automatic machinery of all kinds.

Take away the engineers' contributions to the various industries of the country and we would immediately go back to the time of King Arthur or a little earlier; and, I may say, this is not an exaggeration.

It seems impossible that the engineer will ever make a name for himself as a financier, for an engineering brain seems to have as much idea of dealing in stocks and bonds as the financial head has of the cycle of operation of steam in a simple engine.

The export trade of this country has been made possible by the engineer, not only directly as in steel and iron, but indirectly, in such a product as grain. The reason that we are able to export grain is that one American farmer raises as much grain as three in

England, four in France, five in Germany, and six in Austria. In these figures one can see the enormous waste of labor in these countries, and it is largely because the foreign farmers are not possessed of the mechanical appliances that are so familiar to us.

The social economies and material advancement due to the mechanical skill of our people is so prolific a subject that I have wandered a little from the object of this article—that is, advice to draftsmen.

A great many of the readers of this magazine are probably connected in one way or another with the designing and building of engines. The following notes were slowly gathered during work on both land and marine engines, and in a large part are applicable to all classes of drafting. It will be understood that this is not an attempt to discuss the design of engines or machinery, but merely to call attention to the troubles that crop up during the day's work of a draftsman.

Extreme care and accuracy is the great essential in all designing, and in marine work more especially a lack of attention to detail may occasion the loss of many lives, which on land would mean a financial loss only.

Engines should be designed with reference to accessibility and convenience for rapid overhauling of parts, all valve handles located for ease of manipulation and steam pipes run to allow for expansion, which if not considered will bring undue strains upon them, causing leaking and breaking of flanges. Expanison joints or U bends should be inserted in straight lengths of pipes if they are prevented, at each end, from moving. Ample drainage pipes are necessary to relieve the steam carriers from the entrained water, as it is quite possible for a pressure of from 2,000 to 3,000 pounds to be reached through water hammer; when that occurs something has to go. Use 1 square inch area of drain to about 9,000 cubic inches of steam pipe. Valve hand wheels are almost invariably made too small and the lagging to protect the hand is often omitted.

Reciprocating parts of an engine, especially if for marine work, must be fitted with locknuts or split pins or both. If not, they will certainly become loose. Fouling is one of the chief stumbling blocks of the draftman's life; and I have run up against every available type in the course of the examination of some thousands of drawings. Men often seem to forget that an engine is made to move and not to remain at rest; in consequence many hits take place that are called fouls. Also, that, in marine engines, there is a go-ahead position as well as a go-astern, and if you do not make a hit one way you easily can in the other.

A connecting-rod butt brass will often foul the bedplate or lower corner of the crosshead guide, because it was forgotten that the nuts have thickness; the crosshead and gland nuts of the piston packing; the eccentric straps and bedplates; the suspension rods and the engine columns; the ends of the links when thrown into backing gear are all points where conflict is liable to occur if sufficient care is not taken.

The valve-stem nuts often foul the bonnets or upper end of the stem stuffingboxes on the lower valve-chest cover.

The worst case of fouling that ever came to my notice was this: A horizontal marine engine in a large ship was connected to the shaft by a walking beam placed athwartship under the deck; of course this beam worked up and down, yet the designer forgot that little fact and so did all the examiners;

the boat was built and the engines placed with the beam in mid position. Result: A small trunk house had to be built on the deck to accommodate the up motion of the end of the beam. One can see therefore that it is easy to omit to provide for more simple things than that.

The linear clearance at the ends of the cylinder next the crosshead should be larger than the back end to allow for take up in brasses. Both clearances should be ample; but no larger than absolutely necessary as that means a waste of power.

Turn the piston body smaller than the rings to allow a little bending due to small discrepancies in the piston rod. In that way you will not score or mar the smooth surface of the cylinder barrel.

The auxiliary fittings such as oil, water service, and handling gear should be well looked after, free from interference with the moving parts and accessible to the engineer, and the main bearings should not be designed so that a man has to be an equilibrist to feel them.

Did you ever see a nut in such a position that it needed a cold chisel to set it up? And the corollary to this question is this: Is it not possible to so design any machine that the nuts are accessible to either a straight or crooked wrench, to the utter confusion of the first method mentioned?

Regarding castings: They seldom come to the size expected and this should be allowed for; brackets and bosses should be made a little larger than necessary to allow for fairing up; plenty of finish on pieces joining each other, a sufficient number of core holes, and generous ones, means an even thickness of metal. If of steel, cores must be avoided, use large fillets and few ribs, as the shrinkage in steel is still an unexplainable quality. If a number of pieces such as the parts of a bedplate, which are to be bolted together, are desired, it is preferable to have one set cast and the pattern returned to the shop and altered to suit requirements. My experience has been that this is the only way possible, and not later than this year I have seen several valuable pieces thrown away for the reason that they did not shrink anything like, what in the nature of things, it was supposed they would.

It is strange that with all our steel work we are so far behind the French in this respect. I have in mind some torpedo-boat engine bedplate castings that were turned down by every steel caster in the country because of their thinness and intricacy, yet this identical design was successfully cast a considerable number of times by the French. It is not pleasant to think of and I wish it were otherwise, and I do not see why it cannot be.

A mistake is often made by making the working parts of an engine too good a fit. The fit should be easy, and the pins, except the crankpins, should be flattened on the vertical sides to allow ample oil space. The crankpin end of the connecting rod, and the crank-shaft in the main bearings must have end play to avoid heating; and in the case of a marine engine to allow for the wear of the thrust bearings.

In designing an engine, attention must be paid to the capabilities of the machine shop and the capacity of the machines must be understood, as a boss or two, easily altered on paper, might prevent a cylinder being machined on the big planer.

Use taper holes, etc., that can be reamed by the reamers in stock; do not make the use of special tools a necessity. In these days of close competition, the draftsmen can save much

money by close attention to such small details. Another point to look after is whether your design can be molded easily. A good foundryman is always pleased to answer any question you may ask him, if you do it in the right manner, and you will eventually find that it will not be necessary to ask but a few times before you get the principle of the best foundry work.

Cylinder ports must be unobstructed throughout, ample in area, and the walls well stayed. It gives one an uncomfortable feeling to see the walls of a large cylinder acting like a pair of bellows, and it is not uncommon.

Have your indicator leads straight and accessible from the working platforms, and all your bosses and brackets on your cylinder before casting. It is not easy to put them on afterwards.

The oil service is very important; the pipes should be large, without pockets, and should lead to all working parts. Never allow or provide for oil to be used in the cylinder of a vertical engine, and very little in a horizontal one. It damages the boiler and does not improve the cylinders. I have in mind an engine weighing about 45 pounds per horsepower of 3,300 horsepower, running 360 revolutions per minute, that ran 2,000 miles without a drop of oil in her cylinders. When the covers were taken off, the cylinder barrel was like a black mirror and the boilers in perfect condition. If oil had been used upon this occasion, the grease in the boilers would have been an inch thick.

The dimensions of the engine must be carefully calculated, reference being had to one of similar design known to be good. Do not try to make too many improvements at first. A conservative type of mind in regard to changes from well established designs will save many a bad quarter of an hour; necessarily your design must suit your type of work and it is well to remember that each piece does not constitute a whole engine, but that it must be designed so the whole looks as if it was meant to be one engine, and not as if it were composed of an odd lot of pieces from a good junk pile.

One can easily build an engine that will turn over, but to make one that will do its work more economically than any other is a triumph of good designing.

A last word: Do not worry the head draftsman; he has troubles of his own; get his idea clearly and do not say you understand until you do, and then exhaust your capacity before going to him again. Depend upon yourself to find your own mistakes and not upon him, and if I am not mistaken, your work will soon be recognized as the best in the drafting room. You will then get the fine work that you enjoy. Make a neat drawing if you will, but be certain to make an accurate one; to err is human, but it is not engineering.

SWITCHBOARD CONSTRUCTION

THERE is perhaps no other part of the equipment of a modern electric-light or power plant that has been brought to a higher state of perfection than the switchboard. There was a time, however, when the switchboard was not such a thing of beauty and utility as it is now. In the early days of electric lighting, inventors and manufacturers were altogether too busy trying to build dynamos that would generate and carry their load without requiring the commutator to be turned down at least once a week, to pay much attention to the switchboard.

In those days almost anything answered the purpose. Engineers were too happy if they could get the dynamos to work, and to keep on working, to care much about the appliances through which the current had to pass before being supplied to customers. In many plants a few old ammeters and switches fastened against the side of the building constituted the switchboard. Other plants that were more pretentious, provided a board made of tongued and grooved woodwork. In both these cases the wiring between the various instruments and switches was run altogether on the surface of the board. After a while somebody hit upon the plan of standing the board out from the wall two or three feet, and running the wiring on the back instead of the front. This was a decided advance, even if 1,000-volt wires were run about in a reckless manner and fastened up with wooden cleats.

These old wooden boards stood out two or three feet from the wall and made an elegant place behind them for dumping all sorts of old overalls, old wire, and anything else that was kicking around in the way. This practice became so bad that the Fire Underwriters began to take a hand in the matter, and made a rule that switchboards should be held up on supports so that there would be a clear space of at least 24″ between the bottom of the board and the floor.

A number of bad fires occurred on

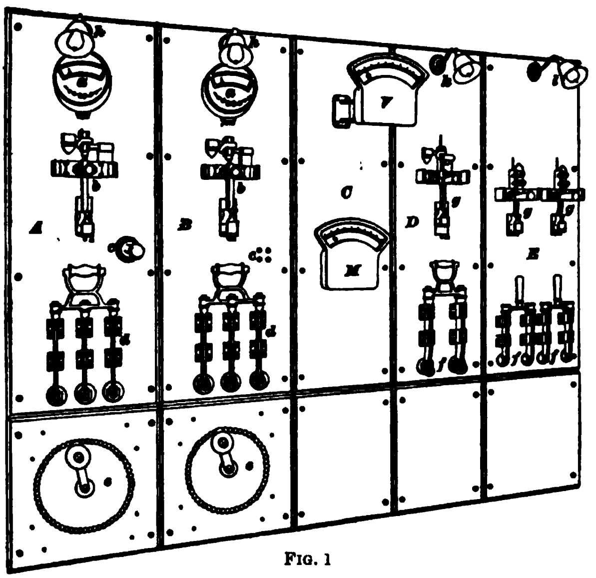


FIG. 1

these old solid wooden switch-boards and resulted in large loss of property Engineers began to pay more attention to the switchboard end of the plant, and the advent of the electric railway hurried things up considerably, because it was soon found that the switchboard appliances formerly in vogue for electric lighting, were altogether too light when it came to handling the heavy and severe work of an electric railway. Efforts were made to make the boards substantial

and at the same time fireproof. The instruments were mounted on slate or marble instead of wood, as formerly. Where the expense of a slate or marble board was not warranted, the board was reduced to a simple open framework of heavy timbers, and the wiring was carefully mounted on porcelain insulators. A skeleton board of this kind is still considered cheap and safe, and in the absence of a slate or marble board it will be found a good substitute.

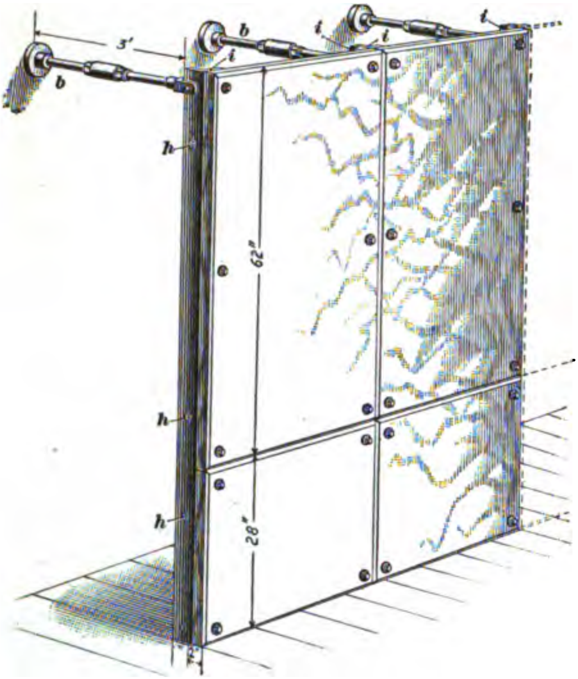


FIG. 2

At first slate and marble boards were of no standard size or arrangement. Each board was designed to suit the particular requirements of the place it was to go in. In fact, it is a very difficult matter to lay down any standard arrangement for switchboards, as the requirements of scarcely any two plants are the same. For central stations, however, the *panel type* of board has been gradually evolved and is now the kind almost universally used.

In the panel type of switchboard the instruments belonging to each generator are mounted on a separate slate board which constitutes a *generator panel*. Also, the instruments belonging to each feeder are mounted on individual panels known as *feeder panels*. Fig. 1 shows a power and lighting board with two generator panels *A* and *B* and two feeder panels *D* and *E*.

Fig. 2 shows the method of mounting the panels on angle irons. Each panel has angle irons bolted along the edge and the projecting flanges are bolted together, thus holding the panels in position. The great advantage of the panel method of construction is that it allows the switchboard to be readily extended, as more generators or feeders are found necessary to keep pace with the growth of the plant. Besides, the instruments belonging to each particular machine or feeder are clearly separated, and this is a great help in the manipulation of the board. Each generator panel is usually equipped with a main switch, rheostat, fuses or circuit-breaker, field switch ammeter, and pilot lamp. One voltmeter is usually made to answer for all the machines by using a voltmeter switch or plugging arrangement by which the voltmeter may be connected to any machine desired.

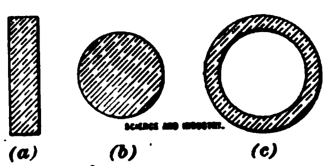
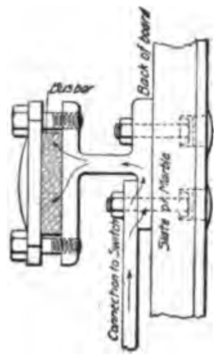


FIG. 3

On the back of the board all the wiring is carried out in a careful manner so that there is little danger of short circuits. The machines connect, through the main switch, to the *bus-bars*. These are heavy copper bars running across the back of the board, and get their name from a contraction of the Latin word "omnibus," meaning "for all," because these bars receive all the current from the machines. The bus-bars are usually flat in cross-section, as shown at (*a*), Fig. 3. This shape has the advantage that it is easy to bolt connections to, and presents a good large radiating surface to the air so that the bar does not get hot to as great an extent as it would were it more nearly square in cross-section. Round bars, as shown at Fig. 3 (*b*), are also used to some extent, and hollow tubular bars as shown at (*c*) have some advantages for alternating-current work where heavy currents have to be handled. Where very heavy conductors are used to carry alternating current the current becomes crowded, as it were, to the outer part of the conductor so that it is better to put the metal in the shape of a tube rather than a solid bar.



It is poor economy to save in copper when installing bus-bars. If the bars are not made large enough, there will be a considerable waste of energy in them, and when it is remembered that this loss goes on day after day the cost of this waste may amount to a surprisingly large amount in the course of a year. About 1 square inch of cross-section should be allowed for every thousand amperes that the bar has to carry. For example, if a bar has to carry 500 amperes, a cross-section of ½ square inch would be sufficient. This could be made in the form of a bar 2 inches wide by ¼ inch thick. Fig. 4 shows one method of supporting bus-bars that has been largely used on marble or slate railway switchboards. The brass casting is bolted to the back of the panel and serves the double purpose of supporting the bar and carrying the current to it. The bar is bolted

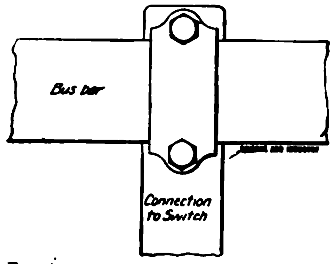


Fig. 4

to the base of the casting and runs down to the main switch. The bus-bar is held firmly in place by the clamp. Fig. 5 shows a simple method of supporting small bars. The bar *B* is clamped up against the support *A* by means of a bolt running through from the front of the panel *C*. Fig. 6 shows some of the methods used for mounting switches and for making connections between the switches and bus-bars. Sometimes these connections are made with copper strips, as shown at (*a*). This is the best method to use when the currents are fairly large. When the current is comparatively small pieces of braided wire soldered into terminals at each end as shown at (*b*) make a neat and sub-

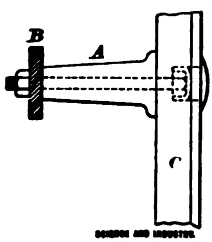


Fig. 5

stantial job of connecting. Fig. 7 shows a cheap and safe way of mounting the comparatively small bus-bars used on alternating-current boards.

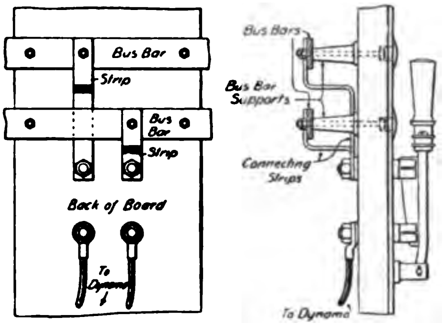


FIG. 6

Unless the output of a station is very large, the bus-bars for an ordinary 1,000- or 2,000- volt alternating-current board are rather small in cross-section so that it is not necessary to provide heavy and rigid supports for them. What is required is good insulation and that the bars be so protected that the switchboard attendant will not be able to come in contact with them. In Fig. 7, A A are two bus-bars which are in the form of heavy wires or copper rods covered with a thick insulation of braiding or taping. A piece of hard fiber B is bolted to the supporting angle irons, as shown, and the insulated bars are run through holes in this fiber. These bars run across the length of the board and are thus firmly supported from each angle iron.

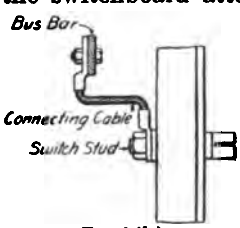


FIG. 6 (b)

When slate or marble boards are used for high-pressure apparatus great care must be taken to see that no metallic veins are present in the slate or marble. If the pressure is over three or four thousand volts it is best not to depend upon the insulating qualities of the panel itself, but support the switch contacts, etc., on hard rubber or other insulating material. Perfectly pure marble or slate is a fairly good insulator, but both are liable to

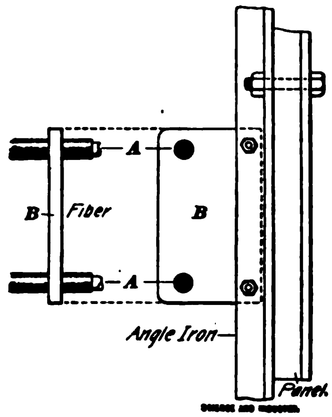


FIG. 7

have metallic veins and both are liable to take up more or less moisture. On many alternating-current boards and on arc boards the pressures may be

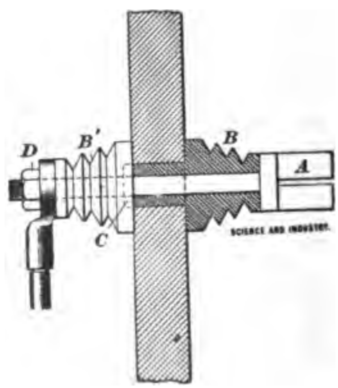


FIG. 8

very high, and it is safest in such cases to bush the switch studs. Fig. 8 shows a switch blade mounting for a high-tension board. A is the blade fastened

to the end of the stud which runs through to the back of the board and is threaded on the back end. B is an insulator made of hard rubber or molded insulating material. This insulator is grooved so that it will present a large leakage distance from the blade to the board. A similar insulator B' is provided on the back and is recessed as shown at C so that B will fit into it and make a long leakage distance from the stud to the board at the point where the joint between the two insulators occurs. The insulators are drawn tightly into place by the nut D.

The above will give the reader a few points regarding the construction of switchboards. The number of details in connection with such boards is almost endless, and there is no more carefully designed piece of apparatus in the station than the switchboard. It is almost absolutely fireproof, and is indeed a marked contrast to some of the earlier forms mentioned at the beginning of this article.

USEFUL FORMULAS—I

JOSEPH E. LEWIS, S. B., JUNIOR MEMBER A. S. M. E.

Strength of Cylindrical Shells Under Internal Pressure, $t = \frac{pr}{s}$.

A FORMULA is merely a concise way of stating the method of solving of a problem. It is usually stated in such a condensed form, however, that the line of argument of which it is the conclusion is not very apparent. Now, in order to use a formula intelligently, one must understand how it is derived. The lack of this knowledge often leads to serious errors, caused by a wrong application of the formula in the solution of a given problem. "A little knowledge is a dangerous thing" when it consists of crowding the memory with miscellaneous facts and formulas without an adequate comprehension of their meaning and application. The power to reason from known facts to a correct conclusion is worth vastly more than a mere knowledge of the facts themselves, and the ability to get down to first principles and think out the solution of your problem is far better than the "hit or miss" application of somebody's formula or "rule of thumb."

Formulas are, however, very useful because they save time, and if one understands their nature and bearing sufficiently well to apply them with certainty, he may gain much by their use. It is the purpose of these articles to explain the derivation and illustrate the application of some of the most useful formulas for the practical man, as well as for the designer and draftsman. The formulas selected are those best calculated to be of assistance in solving the every-day problems of the power plant.

The first formula which we shall consider is that commonly used for calculating the strength of cylindrical shells under internal pressure, such as steam boilers, piping, etc. It takes the form $t = \frac{pr}{s}$, where t = thickness in inches of metal composing the shell; p = internal pressure in pounds per square inch by the gauge; r = the radius of the shell in inches (or one-half the diameter), and s = the stress in the metal expressed in pounds per square

inch of sectional area. s commonly stands either for the breaking strength or else for the working strength of the metal in question. To illustrate; if we say that the breaking strength of steel under tension is 60,000 pounds, we mean that a bar of 1-inch square steel will be broken by a pull of 60,000 pounds. If we say that the working strength of boiler plate is 10,000 pounds, we mean that the stress put upon the metal by the pressure in the shell should never exceed 10,000 pounds to the square inch of section.

The formula may be written $ts = pr$ which, expressed in words, means that in a cylindrical shell under pressure, the thickness of the metal multiplied by the stress to which it is subjected per square inch of sectional area equals the pressure in pounds per square inch multiplied by one-half the diameter of the shell. Having given three of these quantities we can always find the fourth. It will be noticed that the length of the shell does not figure in the solution. Let us now work out the derivation of the formula and we shall discover why.

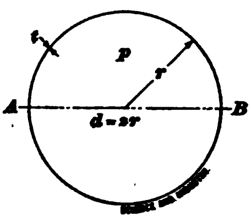


FIG. 1

Referring to Fig. 1 we have a section of a cylinder of any radius r; consider a portion 6 inches long, and imagine that the pressure inside is trying to tear the upper half away from the lower half at the plane AB. This tendency is resisted by the strength of the metal at A and B, and since the metal is not torn it follows that the resistance is just equal to the pull. We may therefore find an expression for the total pull and another for the resistance and put the two equal to each other in the form of an equation.

The total pull is equal to the pressure on the plane AB. The area of AB equals $6 \times 2r$ or $12r$, and the pressure on AB therefore equals $p \times 12r$ or $12pr$. This will be more clearly seen if we imagine only half of the cylinder, as in Fig. 2; the bottom being closed by a flat casting which takes the place of the lower half. Now it is evident that the total force pushing this flat casting away from the half cylinder is found by multiplying the area of the flat surface by the pressure per unit of area. (All dimensions are given in inches.) This gives the same result as above, namely $12pr$. Of course, the lower half of the cylinder in Fig. 1 is pushed away from the upper half with exactly the same force that the flat plate is pushed away in Fig. 2.

Next, to find an expression for the resistance of the metal. The stress per square inch of section is s pounds. The total sectional area is $2 \times 6 \times t$ for the two sides where t is the thickness of the metal. Then the total resistance of the metal is $2 \times 6 \times t \times s$ or $12ts$, and this must be equal to $12pr$. Since $12ts = 12pr$, it follows that $ts = pr$ and $t = \frac{pr}{s}$. The length of the shell cancels out.

To illustrate the use of the formula, let us compute the thickness of a boiler shell to stand 150 pounds. The diameter is 60 inches, and we will take the breaking strength of the metal as 55,000 pounds per square inch. But since the strength of the shell is only that of its weakest point, the value 55,000 must be reduced more or less according to the style of riveted joint to find the actual breaking strength of the shell. The efficiency of single-riveted lap joints is given by Unwin as varying from 40 to 60 per cent., and that of double-riveted lap joints from 60 to 75 per cent. Sir Wm. Fairbain

gives the following values for lap joints: Single riveted, 50 per cent.; double riveted, 70 per cent. Double-riveted butt joints with two butt straps may have an efficiency of 80 or 85 per cent.

In the present case we will assume an efficiency of 80 per cent. 80 per cent. of 55,000 equals 44,000, which is the breaking strength of the joint, and therefore of the shell as a whole. 44,000 cannot be used as the value of s, however, since this value must be the working strength of the shell and not the breaking strength. To find this we will divide by a factor of safety. $4\frac{1}{2}$ is sufficiently good, and $44,000 \div 4\frac{1}{2} = 9,800$, nearly, which we may use as the value of s. We have then, $s = 9,800$; $p = 150$, and $r = 30$, to find the value of t. $t = \frac{p\,r}{s} = \frac{150 \times 30}{9,800} = 0.459$, or nearly $\frac{1}{2}$ inch. The shell should therefore be $\frac{1}{2}$ inch thick.

To illustrate another application of the formula let it be required to find the pressure that will burst a seamless copper tube 3 inches in diameter, the metal being $\frac{1}{16}$ inch thick. Take the breaking strength of copper as 30,000 pounds per square inch. We may transpose the terms of the formula as follows: We have $t = \frac{p\,r}{s}$, then $t\,s = p\,r$ and $p = \frac{t\,s}{r} = \frac{1 \times 30,000 \times 2}{16 \times 3} = 1,250$ pounds, since $r = \frac{d}{2}$. The safe working pressure for this tube would be about one-fifth of this or 250 pounds for the most favorable conditions; that is, where there is no vibration or other hard usage. Take the case of a feedwater heater, however, with 3-inch tubing in the coil subject to the vibration of the exhaust steam and feed-pump and a much thicker gauge should be used for 250 pounds pressure; or, what is the same thing, a less pressure, say 150 pounds, used with the tube upon which we have figured above. A large amount of common sense, and a thorough knowledge of practical conditions are the only safeguards against misleading or even dangerous results from the use of this or any other formula.

Take another case. Find the safe working pressure for standard 2-inch wrought-iron pipe. The outside diameter of the pipe is 2.375 inches, the inside diameter is 2.067 inches, the mean diameter is the inside diameter plus one-half of the difference, or 2.221 inches. Hence $r = 1.11$ and $t = .154$.

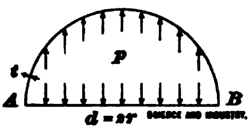


FIG. 2

The breaking strength of wrought iron may be taken as 45,000 pounds. The strength of the weld, however, is a somewhat uncertain quantity. In a large number of tests the efficiency of welds was found to vary all of the way from 40 per cent. to 90 per cent. The great majority of tests, however, show from 60 per cent. to 90 per cent., so that we may take 50 per cent. as a pretty safe figure. 50 per cent. of $45,000 = 22,500$. Take 5 as the factor of safety and $s = 22,500 \div 5 = 4,500$ pounds. Then $p = \frac{t\,s}{r} = \frac{.154 \times 4,500}{1.11} = 624$ pounds as the working pressure. Owing, however, to the rough treatment which piping has to stand, and allowing for corrosion, etc., it is seldom advisable to use standard weight pipes for pressures exceeding 500 pounds, particularly as standard pipe is tested to only 500 pounds by the manufacturer. Extra heavy pipe should be used for greater pressures.

The above illustrations will serve to show the manner in which the formula is applied as well as the care which

must be exercised in its use. Practical conditions cannot be ignored.

The breaking strength, or more properly speaking, the tensile strength (T. S.) of various metals may be found in any engineering handbook. We will note a few average values here for convenience. Boiler plate 55,000 to 60,000 pounds; wrought iron 45,000 to 50,000; cast iron, 15,000 to 20,000; cast copper, 24,000; rolled or drawn copper, 30,000 to 35,000. Minimum values should in general be used.

The factor of safety varies with the nature of the load and other practical conditions. In general, for a dead load 4 to 5 is sufficiently large, for a moving load 5 to 6, and under very trying conditions greater than 6. It may also be observed that a less factor of safety will suffice for hydrostatic pressures than for steam pressures; thus, the shell of a Berryman heater may be thinner than that of the boiler with which it works, because the rupture of the heater would mean only some inconvenience, while an explosion of the boiler would result in serious loss of property and even of life.

The formula $t = \frac{p\,r}{s}$ gives the thickness of shell to withstand the stress along a longitudinal section of the cylinder; that is, along a line running lengthwise of the shell. It will be interesting to learn the magnitude of the stress upon a transverse section, or along a line running around the circumference. It will be readily seen that the stress in this direction is that due to the pressure upon the heads tending to stretch the shell lengthwise.

The area of the head is $3.142 \times r^2$ and the total pressure upon it equals $3.142 \times r^2 \times p$ or $3.142\,p\,r^2$. This total force is resisted by a ring of metal of thickness t, and circumference, $2 \times 3.142 \times r$ or $6.284\,r$. The sectional area equals $6.284\,r\,t$; and if the stress per unit of area is s, the total resistance is $6.284\,r\,t\,s$, which just balances the pull. Then $6.284\,r\,t\,s = 3.142\,p\,r^2$, and $s = \frac{3.142\,p\,r^2}{6.284\,r\,t} = \frac{p\,r}{2\,t}$, which is just one-half of the stress on the longitudinal section $\frac{p\,r}{t}$. For this reason we always neglect the transverse stress since the shell will always split longitudinally first; and this is also the reason why the girth seam of a boiler is only single riveted.

In conclusion we will refer to a modification of the formula used for calculating the thickness of cast-iron pipe. It is as follows: $t = \frac{p\,d}{4{,}000} + 0.3$. It is derived from the formula $t = \frac{p\,r}{s}$ by substituting $\frac{d}{2}$ for r and adding the constant 0.3 when we have $t = \frac{p\,d}{2\,s} + 0.3$. Now let $s = 2{,}000$ pounds and we have the formula given above. A great number of formulas have been proposed for figuring cast-iron pipe. Mr. P. H. Baermann, in a paper read before the Engineer's Club, of Philadelphia, enumerated no less than twenty. The formula suggested above is one of the simplest and best. To compute the thickness of the flange use the constant 0.5 instead of 0.3, the formula remaining otherwise unchanged, thus: $t = \frac{p\,d}{4{,}000} + 0.5$. All dimensions in the above formulas are in inches.

WIRING CALCULATIONS FOR MOTOR AND LAMP CIRCUITS

FRANCIS H DOANE

DERIVATION OF FORMULA—APPLICATIONS

ALL conductors of electric currents have the property of resistance, which tends to retard the passage of an electric current through them. Energy is expended in forcing current through a conductor against its resistance. Allowance for this loss is made in wiring calculations.

When speaking of the diameter of a wire we say that its diameter is a certain number of mils. A mil is $\frac{1}{1000}$ of an inch. A circular mil is an area equal to the cross-sectional area of a round wire 1 mil in diameter. The area in circular mils of a wire 100 mils in diameter will be $100 \times 100 = 100^2 = 10,000$ circular mils. In general, the area in circular mils equals the square of the diameter expressed in mils. The resistance of a wire increases as the length of the wire is increased, and decreases as its cross-sectional area is increased. A long fine wire has a much greater resistance than a short thick wire. The resistance of 1 foot of commercial copper wire, 1 mil in diameter, at a temperature of 75° F., is 10.8 ohms, approximately. If a wire is 10,000 feet long and 1 mil in diameter (cross-sectional area 1 circular mil) its resistance will be $10,000 \times 10.8 = 108,000$ ohms, or $10.8 \times d$ where d equals the length of wire in feet. Now, suppose this 10,000-foot length of wire has a diameter of 100 mils, instead of 1 mil, and a cross-sectional area of 100^2, or 10,000, circular mils. The resistance of 10,000 feet of wire 1 circular mil in area is 108,000 ohms, therefore if the cross-sectional area is increased to 10,000 circular mils, the resistance of the wire will now be $\frac{1}{10000}$ of $10,000 \times 10.8$ or

$$\frac{10,000 \times 10.8}{10,000} = 10.8 \text{ ohms.}$$

A No. 10 B. & S. wire has a resistance of nearly 1 ohm per 1,000 feet and a little less than 10 ohms for 10,000 feet, its diameter being 101.89 mils. To simplify the work, we use a wire having a diameter of just 100 mils. This wire thus has a slightly higher resistance, for a given length, than a No. 10 wire. We can now write a formula that will give us approximately the resistance of any copper conductor.

$$R = \frac{10.8 \times d}{c.\,m.}.$$

R = resistance;
d = length of wire in feet;
$c.\,m.$ = cross-sectional area of wire expressed in circular mils.

When a direct current is flowing through a wire and a sensitive voltmeter is connected to two points on the wire, say 10 feet apart, a small deflection of the voltmeter needle will be noticed. This reading, expressed in volts, denotes the number of volts necessary to force the current flowing through the wire from one point to the other against the resistance of the 10-foot section of wire. If the current is known and the resistance of the section of wire, the volts reading on voltmeter will be found to equal the current multiplied by the resistance.

$$R \times C = V.$$

R = resistance in ohms;
C = current in amperes;
V = loss of volts in line.

To find the drop in volts in a conductor carrying a current C, we have the formula $V = \dfrac{10.8 \times d \times C}{c.\,m.}$ which equals $C \times R$. If we allow a certain drop in volts and wish to find the size of wire which will conduct the cur-

rent with this given drop in volts, we change, by means of algebra (multiply each side of the equation by $\frac{c.\,m.}{V}$) the previous formula so as to read

$$c.\,m. = \frac{10.8\,d \times C}{V}.$$

Nearly all forms of wiring formulas are based on this fundamental formula. We will apply the formula in determining the proper size of wire to use in installing a 10-horsepower, 500-volt motor of 85 per cent. efficiency. The distance between motor and generator is 2,000 feet, the length of line wire being $2 \times 2{,}000$ feet or 4,000 feet. We will allow a drop in volts on the line wire of 5 per cent. of the generator voltage.

Volts at generator will be

$$\frac{500}{.95} = 526, \text{ nearly;}$$

Volts lost in line $526 - 500 = 26$;

1 H. P. = 746 watts;

10 H. P. = 7,460 watts.

The watts utilized by the motor divided by the E. M. F. of the lines at the motor end, gives the current taken by the motor.

As the motor has an efficiency of 85 per cent., the total number of watts delivered to the motor will be $\frac{10 \times 746}{.85}$ and the current C will be equal to $\frac{10 \times 746}{500 \times .85}$.

We can thus change our formula to read

$$c.\,m. = \frac{\text{H.P. of motor} \times 746 \times 2\,D \times 10.8}{E\,V\,K}.$$

Where $c.\,m.$ = circular mils;

E = E. M. F. of motor in volts;

V = loss of volts in line;

D = distance from generator to motor in feet;

$2D$ = length of line wire;

K = efficiency of motor.

Let us now substitute the values given in the problem, in this formula.

$$c.\,m. = \frac{10 \times 746 \times 4{,}000 \times 10.8}{500 \times 26 \times .85} = 29{,}165.$$

Looking in a wire table we see that this size of wire is about the size of a No. 6 B. & S. wire, which should be used.

To illustrate the method of determining the size of feeder wire to use from a dynamo to the center of distribution of a lighting circuit, we will solve the following problem:

Example.—What wire should be used to carry 225 amperes a distance of 600 feet, the allowable drop being 6 per cent., and the E. M. F. at the end of the circuit 115 volts?

The total length of feeder wire will be $2 \times 600 = 1{,}200$ feet.

$$\text{Volts at dynamo} = \frac{115}{.94} = 122.3;$$

$$\text{Volts lost in line} = 122.3 - 115 = 7.3;$$

$$c.\,m. = \frac{10.8 \times d \times C}{V}$$

$$= \frac{10.8 \times 1{,}200 \times 225}{7.3} = 399{,}452.$$

A 400,000 circular mil cable would probably be used.

These formulas may be applied to many varieties of wiring problems, such as determining the size of feeders, mains, branch mains, service mains, etc.

THE ELECTRICAL ENGINEER IN THE PHILIPPINES

GEORGE E. WALSH

IN many respects the Philippine Islands offer excellent opportunities for the electrical engineer either in connection with the army or with private corporations which are engaged in exploiting the islands for commercial purposes. One of the first necessities of a plan of successful occupation by the American army was the development of an electrical system which would bind the different important towns and cities together. The army immediately proceeded to string telegraph and telephone wires over the interior of the islands, and the navy laid cables from one island to another and along the coast where important towns and cities are located.

The need of electricians in both army and navy was so great that special inducements were offered to get competent men to enlist in this department. It may not be generally known that both the army and navy employ a corps of skilled electrical engineers capable of performing both the roughest and the most technical work in the field. These men join the army or navy for the double purpose of getting the experience which comes from cooperating with a corps of highly trained experts, and for the opportunities offered for advancement. Young men who have joined the electrical corps of either army or navy have after a few years of service found themselves capable of occupying responsible positions in private companies.

The pay is not extraordinarily high in either the army or navy, but the experience and training which the men receive are worth far more than the salary. In order to be successful the electrical experts have to follow in the wake of the fighting army or navy, and often while under fire from the enemy string the wires or lay the cables under the water. Working under such disadvantages is not always desirable, but the men who have passed through the experience have come forth with a certain amount of self-reliance which speaks well for their future.

But the fighting is about over in the Philippines now, and the electrical engineer is needed more in the interests of peace and industrial development than for war. The army of electrical experts and beginners has a field for exploitation unsurpassed in any other country. Under American stimulus the towns and cities are rapidly awakening to the necessity of adopting modern methods of industrial progress. The electrician is one of the most important factors in this life. The proposed laying of the Pacific cable from San Francisco to Hawaii and the Sandwich Islands, and thence to Manila, will further stimulate the efforts of the electricians. There will immediately be a demand for more cables along the coast. These will not be laid by the navy in the future so much as by private corporations. The United States government stands on record as opposed to laying and owning cables, but the needs of the islands are such that these means of intercourse must be had. Already half a dozen companies have been organized in the Philippines for laying cables along the coast, and they will find ample opportunity to secure contracts when the new Pacific cable is laid.

The work of laying the coast cables enables young electricians to find employment that will train them for a special field of electrical engineering not now overcrowded. Indeed it is

difficult to secure the number of trained experts in this line to fill all contracts in the Far East. Capable assistants who can carry on the work projected are almost as scarce as natives who can install an electric plant for manufacturing purposes. Modern cable-laying ships and machines have in recent years greatly simplified the labor of laying cables in deep and shallow water, but the mechanism of these boats is such that experts are demanded to operate them. Consequently there is no diminution in the demand for experts, but their ability should be of a different order. They should make a specialty of ocean and coast cable-laying machines and ships.

On the islands the work of installing electric plants has been going on rapidly. Last year nearly half a hundred different private companies were organized for building and equipping electric plants for manufacturing and commercial purposes. The telephone and telegraph lines outside of Manila are still in an undeveloped state, but the need of them is general and immediate. The foreign population of Manila is large enough to make the use of the telephone and telegraph profitable to the companies operating them, but in the smaller towns it requires some little education to induce the inhabitants to use either. On the other hand the army has strung wires so generally throughout the islands that the natives have been educated to an appreciation of the telephone and telegraph so that companies organized to extend the systems have the ground already broken for them.

One of the most important developments of electrical engineering in the Philippines will be that connected with the infant industries of the islands which have heretofore languished for the lack of brains, capital, and modern inventions. The sugar and hemp industries will both feel the effect of the American spirit and energy. The need today is felt as much for capable scientific men of business as for capital. A good many of the army electricians have left the government's service to take positions in private concerns at good salaries. Electric power will prove more economical in the Philippines than steam or compressed air. This has been demonstrated all along the coast and interior, and the equipment of most of the new manufacturing plants with electricity is almost a foregone conclusion.

The salaries paid for electrical experts in the Philippines vary a good deal according to the work required of them. In the army, linemen receive from $18 to $25 per month and their food and shelter and medical help. A sergeant of an electrical corps receives as high as $30 and $40 per month. These men are employed to do work of an ordinary electrical character, and when we go up to the higher offices larger salaries are offered. In considing the wages paid in the Philippines it must be remembered that the cost of living is much smaller than in this country, especially outside of Manila, and in comparison to the wages and salaries paid heretofore to the natives these rates are high indeed.

A little more is paid to electricians outside of the army and navy, and private companies pay telegraph operators, linemen, and repairers from $40 to $60 per month. Electrical engineers capable of taking hold of plants and operating them, or installing new ones receive from $1,000 to $1,800 a year. Recently a man was engaged to go out to the islands from New York to superintend the equipment of a plant at a salary of $5,000 a year and his expenses.

In considering the opportunities in

the Philippines for electricians it must be remembered that certain qualifications are necessary that may not apply to one in this country. The first essential is good health. The work is rough and carried on in a half-settled country, with more or less exposure to fevers, and only those accustomed to outdoor work can stand the strain. The second qualification is self-reliance and an inventive mind which will enable one to make the most of his surroundings. The electrical engineer installing a plant fifty miles in the interior may find problems facing him that no textbook ever told him how to solve. There is no data at hand to help him. Neither has he all the modern materials and appliances for overcoming the difficulties facing him. In short, he is thrown upon his own resources for solving the problems, and upon his power to do this will often depend the measure of his success. Such men are in demand in any new country, and the Philippines are no exception to the rule. Men who have the spirit, energy, and genius to carve out their way in spite of all opposition and difficulty can find no better field for endeavor than these far eastern lands of ours; but there is no opportunity for the man—electrician or otherwise—who can merely follow the beaten track, and reproduce only what he has been taught. There are wide possibilities in the electrical and engineering field in the Far East, but they can only be successfully carried out by constant endeavor, hard and intelligent work, and the application of a genius for solving the knotty problems that always arise in a new land. The pioneers in the electrical field may, within a decade, find their reward in ample and sufficient monetary profits which will make them forever independent. It is the land for the young and ambitious man who is thoroughly competent in his line, but not for the man who is good at nothing in particular, and who can only indifferently apply himself to any one of half a dozen different industries.

ARTIFICIAL LEATHER

UNITED States Consul General Hughes, at Coburg, Germany, reports that, according to the German press, fibroleum, a new artificial leather, has just been invented by a Frenchman. It consists of pieces of refuse skins and hides, cut exceedingly small, which are put into a vat filled with an intensely alkaline solution. After the mass has become pulpy it is taken out of the vat, placed in a specially constructed machine, and after undergoing treatment therein is again taken out and put through a paper-making machine. The resulting paper-like substance is cut into large sheets, which are laid one upon another, in lots from 100 to 1,000, and put into a hydraulic press to remove all moisture. The article is strong and pliable, and can be pressed or molded into all kinds of shapes and patterns. It is said to make the best kind of wall paper. Decorators who have used this article speak of it in the highest terms.—The Metal Worker.

NOTES

Under the title "Useful Formulas" we commence in this number a series of articles by Mr. Joseph E. Lewis, B. S., Jun. Mem. A. S. M. E. Among the formulas which will be discussed in the forthcoming articles are the following: $S = \frac{WL}{ck(T-t)}$ for figuring condensing surface, $h = 2.3\,p$ for finding hydraulic head, $v = \sqrt{2gh}$ for finding the velocity of falling bodies, $f = \frac{JNy}{I}$ for calculating beams and cantilevers. Other formulas will be treated as they suggest themselves, care being taken to present those which are of the most practical value to the men in the shop and the drawing room.

United States Consul Haynes, of Rouen, France, in a recent report states that the metric system is now in use in the following countries: Germany, Austria-Hungary, Belgium, Spain, France, Greece, Italy, Netherlands, Portugal, Roumania, Servia, Norway, Sweden, Switzerland, Argentine Republic, Brazil, Chili, Mexico, Peru, and Venezuela, and recommends that Americans having dealings with any of these countries use the system. It has been long urged that the United States adopt this system as a standard, and after the change had once been made it would certainly be more convenient to use than the present ones.

In promulgating your esoteric cogitations or in articulating superficial sentimentalities and philosophical or psychological observations, beware of platitudinous ponderosity. Let your conversation possess clarified conciseness, compacted comprehensiveness, coalescent consistency, and concatinated cogency. Eschew all conglomerations, flatulent garrulity, jejune babblement, and asinine affectations. Let your extemporaneous descantations and unpremeditated expatiations have intelligibility, without rhodomontade or thrasonical bombast. Sedulously avoid all polysyllabical profundity, pompous prolixity, and ventriloquial verbosity. Shun double entendre and prurient jocosity, whether obscure or apparent. In other words, speak truthfully, naturally, clearly, purely. Don't use big words."—Recreation.

A record breaking automobile run is reported from Chicago. The machine in question was equipped with storage batteries and made a run of 187½ miles on one charge. This record to our knowledge has never before been equaled.

Prof. P. G. Tait, who for forty years occupied the chair of Natural Philosophy in the University of Edinburgh, has recently died. Professor Tait was one of the distinguished men of his time, and his death is a distinct loss to science throughout the world.

A school of technology is to be added to the other departments of Northwestern University, Evanston, Ill. The school will comprise courses in mechanical and electrical engineering.

Turpentine and camphor are generally used as lubricants for drilling glass, but a simple solution of soap in water answers very well.

A new floating dry dock has been launched at Havana. It will accommodate vessels of 6,000 tons, and will be ready for use in about a month.

The Pressed Steel Car Co., of Pittsburg, has received an order for 250 steel gondola cars for use on the New South Wales Government Railways.

ANSWERS TO INQUIRIES

NOTE.—*Address all letters containing questions to be answered in this department to Editor* SCIENCE AND INDUSTRY, *Scranton, Pa.*

1. *Put this address both on the envelope and at the head of the letter.*

2. *Only questions of general interest to our readers will be answered.*

3. *No questions will be answered by mail.*

4. *Drawings or sketches accompanying questions should be made on a separate sheet of paper, and should be drawn as clearly as possible.*

5. *The names and addresses of the writers must accompany the letters, or no attention will be paid to them. Unless otherwise requested, we will publish only the initials and address of the writer.*

6. *Reference to inquiries previously answered should give date of issue and number of question.*

7. *Questions cannot be answered in the issue of the month immediately following their receipt.*

8. *Any book not out of print and for sale by regular dealers may be ordered through the magazine.*

9. *We will not undertake to calculate windings of dynamos and motors, as this involves considerable work and is seldom justified.*

MECHANICAL

(29) On starting away with a certain train, the engine blows out her left cylinder head. The only available engine, while going to couple on to the first one, breaks her right crosshead; thus each engine has one side disabled. (*a*) Could I put both engines on the train as a double-header, one engine facing east and the other west, both engines being of the same size and make? (*b*) Would either engine have power enough to slip the drivers? (*c*) If so, could they be run as proposed? (*d*) How do you cut a cylinder out of action in the case of a "simple" locomotive? (*e*) Can a cross-compound locomotive with one cylinder disabled run light for a distance of 10 miles, having to start herself?

R. R. R., Manitoba, Can.

ANS.—(*a*), (*b*), (*c*) Your idea evidently is that the combination you propose would be equivalent to one of the engines running in its normal condition. If the engines were so placed that the crankpins on the two working sides were a quadrant apart, and were to *remain in that position*, then what you have in mind would, of course, be approximated to. They would, as a matter of fact, however, not remain long in their initial position, for slipping would be likely to occur at any moment, according to the number of drivers and the state of the rails, to say nothing of the matter of handling. And, besides, even if they *were* sister engines, the diameter of the two sets of drivers might vary, owing to one engine having been running longer and so having her tires worn down more; or its tires may be the softer of the two. However, it *is* a matter of common experience for an engine to run with only one side working; therefore you can safely assume that two in that condition would be an improvement on only one. The drawback attaching to the one engine applies to the double-header also, namely, the difficulty of making starts, if both engines should be on the center together. When once fairly away, the momentum will carry them over the centers, but still they are likely to stall on grades. The two engines should face the same way, and not as you propose. (*d*) By clamping the valve so as to cover both steam ports. In the absence of marks on the valve rod locating this central position, it may be ascertained without lifting the cover, by opening both cylinder cocks and giving her a little steam and then moving the valve along until no steam appears or, as the seat may not be quite tight, until the minimum blow occurs. (*e*) Yes. If, however, the non-crippled side is on the center, you will have to pinch her over in order to make a start. In case of a broken cylinder head, if nothing is left in to foul the piston, you need not uncouple the main rod nor the side rods. If the crosshead is broken, take down the main rod if the break requires it, but not the main or side rods, unless injury to them or their pins demands it. When an engine is going to run at speed, her rods should *never* be removed, if such can be avoided.

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(30) (*a*) On page 79 of the "Mechanics' Pocket Memoranda," you give a table of heating surfaces in square feet allowed per boiler horsepower for different types of boilers. How have these numbers been obtained? Are they deduced from tests? (*b*) In computing the heating surface of a vertical tubular boiler, do you count the surface of the tubes above the water level and hence the steam space, as heating surface? The tubes run through to the top head.

G. D., Windber, Pa.

ANS.—(*a*) The figures given in the table referred to represent the average practice of American boilermakers in rating boilers. They are the mean of numerous tests and represent fairly well the capacity of a boiler to furnish steam for the average slide-valve engine of the same horsepower under the average conditions as to steam consumption of the engine, average combustion rate, and

average rate of evaporation. Even at its best this method of expressing the capacity of a boiler is unsatisfactory for cases where the conditions differ materially from average conditions. (*b*) It is the most general practice to consider the entire area of the tubes as heating surface, although strictly speaking the area above the water level should be considered as superheating surface.

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(31) Please answer the following inquiries: I understand that when a wheel moves along a surface, the point *c*, Fig. 1, on the wheel moves faster than the point *b*, and that when *e* is at *f* it is at its greatest speed, gradually diminishing in speed until it gets to *e*, and then increasing again. (*a*) Is this so? (*b*) Why? (*c*) Would this be true in the case shown in Fig. 2? (*d*) Why? E. E. K., Chicago, Ill.

ANS.—(*a*) Yes. (*b*) At the instant at which the point *b* is in contact with the rail, it is at rest, and all other points of the wheel revolve about it as a center. This is, however, true only for the infinitesimal period of time during which the point is actually in contact with the rail. At this instant, then, the angular velocities of all other points on the wheel are the same, as they revolve together about the point of

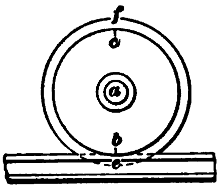

FIG. 1

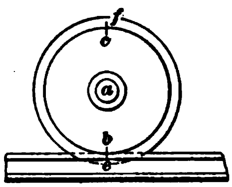

FIG. 2

contact. Since the linear velocity is equal to the angular velocity multiplied by the length of the radius of rotation it will be seen that the velocity of any point is at this instant directly proportional to the length of its radius, that is, its distance from the point of contact, and since the radius is greatest at a point diametrically opposite the point of contact, it follows that the velocity at this point, that is, the point *c*, in Fig. 1, is the greatest. When the wheel revolves to a position where the point *c* is in contact with the rail, this point becomes the center of rotation and is, for the instant, at rest, and it follows that at intermediate points the velocity has varied from a maximum at the point diametrically opposite the point of contact, to zero where it is itself in contact. (*c*) Yes. (*d*) Assume that in Fig. 2, a second rail rests on top of the wheel and runs forward, without slipping, as the wheel rotates. The wheel may then be said to rotate with reference to either rail. With reference to the upper rail, the velocity of the point diametrically opposite the point of contact, that is, the point *b* in Fig. 2, is greatest; with reference to the lower rail the velocity of the point *c* is greatest, as in the case described in (2).

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(32) (*a*) If in a non-condensing engine, using steam at 150 pounds gauge pressure, you add 10 pounds to the back pressure, and then increase your initial pressure to obtain the same power as before, how much will you increase the fuel bill? (*b*) Suppose the engine is condensing, and all other conditions remain the same, how much will the fuel bill be increased?

W. S. B., Butte, Mont.

ANS.—(*a*) and (*b*) The problem may be solved accurately enough for all practical purposes as follows: With a fixed cut-off engine, the initial pressure must be increased by the same amount the back pressure was increased, in order that the same mean effective pressure as before may be obtained. That is, if the back pressure is increased 10 pounds per square inch, the initial pressure must be raised to $150 + 10 = 160$ pounds. As the power of the engine is to remain constant, the same volume of steam will be used per hour as before, but as now the steam is at a higher pressure, a greater weight will be used. From the Steam Tables, a cubic foot of steam at 150 pounds gauge pressure weighs .369478 pound, while a cubic foot at 160 pounds gauge pressure weighs .390636 pound. This shows that a weight of steam greater by

$$\frac{(.390636 - .369478) \times 100}{.369478} = 6 \text{ per cent.},$$

nearly, is used per hour. To generate this greater amount of steam, we can assume, without introducing any very serious error, that the same percentage of extra coal will have to be burned. It does not make any difference in the calculation whether the engine is condensing or non-condensing.

***

(33) (*a*) We have a pumping station 250 feet lower than our reservoir. The pump is a Deane duplex, 14″ × 7″ × 10″, with a 6-inch suction and delivery pipe. The water has to be lifted 12 feet to the pump? Would a 10-inch suction pipe work on this pump? We intend to place an 8-inch discharge pipe on it also. (*b*) How much more power does it take to lift water 12 feet than it does to elevate it 12 feet? (*c*) Which is the best automatic damper regulator? (*d*) Do damper regulators always work satisfactorily?

D. S. P., Brattleboro, Vt.

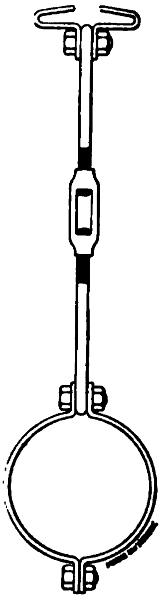
ANS.—(*a*) Yes. (*b*) The same amount of power is required in either case. (*c*) We would advise you to write to the different makers of damper regulators for their catalogues; you should then study the construction of the different makes, and thus place yourself in a position to make an intelligent

selection to suit the conditions existing in your plant. (*d*) With intelligent supervision, yes; if neglected, no.

***

(34) The accompanying sketch shows a standard type of steam-pipe hanger. Please tell me how to calculate the proper dimensions of the materials used in its construction. The round iron suspension rods have a welded eye on one end and a thread on the other end to suit the turnbuckle. Can you suggest any improvement on this type of hanger.

X. X., Pittsburg, Pa.



ANS. — Calculations for hangers like this can be made, but they involve considerable work, which is seldom justified. Any one of a practical turn of mind and a little experience, knowing the size pipe for which the hanger is intended, could easily proportion it to the proper size. The only force exerted on the rod is a straight pull downward, so, knowing the weight of the pipe and the safe tensile strength of the rod, its size can be quickly determined. We should recommend that the rod be from ½" to 1" in diameter, and the flat iron from ½" × ¼" to 1" × ⅜", according to the size and weight of the pipe.

***

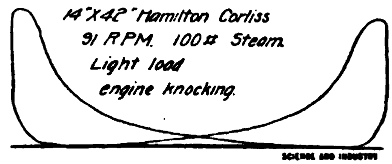
(35) (*a*) In which case will a tugboat engine develop the greater indicated horsepower, when towing or when running light, assuming that the cut-off position of throttle and boiler pressure is the same in both cases? (*b*) Suppose a tugboat is towing a raft of logs for an hour with a certain throttle position, cut-off, and boiler pressure. Now, suppose that the tow line is cast off, and the throttle position, cut-off, and boiler pressure remaining as before, the tugboat runs light for an hour. In which case will the coal consumption be greatest, and in which case will the mean effective pressure in the cylinder be greatest?

A. F., Port Arthur, Canada.

ANS.—(*a*) Under the assumed conditions the indicated horsepower will be greater when the tugboat is running light. With the assumed conditions the mean effective pressure is the same whether the tug is towing or running light; but, when not towing, the load on the engine is decreased and hence it speeds up, thus increasing the indicated horsepower, which increase is expended in driving the tug faster through the water. (*b*) As the indicated horsepower is increased under the assumed conditions, the coal consumption will be greater when running light. The throttle position, point of cut-off, and boiler pressure remaining the same, the mean effective pressure in the cylinder is not affected and remains the same whether the engine is running slow, as in towing, or fast, as when running light. In order to change the mean effective pressure, it is necessary to change either the throttle position, the point of cut-off, the boiler pressure, or the back pressure; the latter method is generally impracticable, however.

***

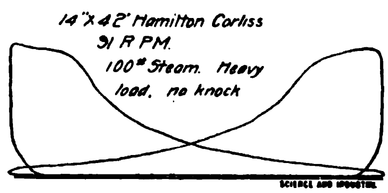
(36) The accompanying cards were taken from a 14 × 42 Hamilton-Corliss engine running non-condensing, and making 91 revolutions per minute. The engine knocks at



times when running under light load, but is quiet when more load is put on. Please tell me what defects are shown by the cards and how to correct them.

C. C. C., Circleville, O.

ANS.—The cards show, by the rounded admission corners, that there is no lead. Increase the angular advance slightly. We think that the knocking under a light load is more likely to be due to a mechanical defect than to a wrong valve setting, and would suggest that you try the alinement of the engine. You will understand that as a



matter of course we cannot tell without a personal examination where the defect lies, and can only suggest a systematic search for it.

***

(37) (*a*) Please tell me how to design strap and shoe brakes and illustrate with examples. (*b*) Can you recommend any works on conic sections and calculus, suited for private study?

H. M. K., High Point, N. C.

ANS.—(*a*) It would take more room to answer this question satisfactorily than we can allow in these columns. We should advise you to consult such a book as "Steam

Engine Design," by Prof. J. M. Whitham. This book can be secured from the Technical Supply Co., Scranton, Pa., for $5.00. (*b*) If you wish to study conic sections and calculus at home, our advice to you would be to enroll as a student in the International Correspondence Schools, as their textbooks are the best we know of for private study. By addressing them on the subject you will receive full information in regard to the course you wish to take.

***

(38) Please explain how to calculate the size, thickness, and number of the threads per inch of an eyebolt tapped into an

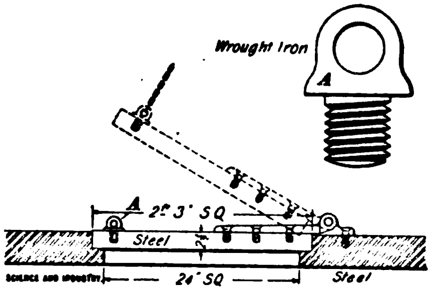


FIG. 1

armored shutter, as shown in Fig. 1, to lift it with safety.

F. B. W., Newport News, Va.

ANS.—This depends on the tensile strength

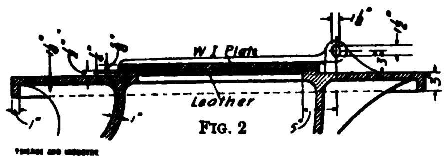


FIG. 2

of the material used. See "Kent's Mechanical Engineers' Pocketbook." We have found the arrangement shown in Fig. 2 a very satisfactory one for a water tank. The bolt

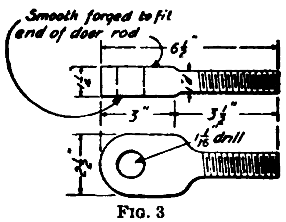


FIG. 3

shown in Fig. 3 has a nut on the under side of the door and is connected to a forked rod instead of a chain.

***

(39) (*a*) My boiler has bulged about 18 in. × 8 in. and ½ in. deep. Please tell me how this happened, and whether the bulge is dangerous. (*b*) I have a double hoisting engine having only one exhaust pipe common to both engines. When steam is turned on, it blows through badly, although I have put in new piston rings. Please give me the best way to remedy the trouble.

C. H. C., Bridgeport, Tex.

ANS.—(*a*) We presume you refer to the crown sheet of a firebox boiler. If so, the bulging is due either to low water or to allowing scale or grease to accumulate on the crown sheet. In either case it is the result of carelessness on the part of the attendant. You should immediately call in a competent boilermaker to repair the boiler. (*b*) Not being able to make a personal examination of the engine, we cannot tell what the trouble is, but think most likely that the cylinders are badly worn and need reboring. It may be that the slide valves leak badly, allowing steam to pass from the steam chest directly to the exhaust pipe. A thorough examination should show at once where the trouble is; the remedy is then obvious.

ELECTRICAL

(40) Please explain how the current works its way through an arc lamp when one end of one coil is connected to the positive wire and one end of another coil is also connected to the positive wire.

W. M. C., Carlisle, Pa.

ANS.—We are not sure that we understand just what is meant by your question. Arc lamps are usually run in series, and are provided with two coils. One of these is of coarse wire, and is in series with the carbons. Practically the whole current passes through it. The other coil is of fine wire and is connected across the arc. When the current enters the lamp it divides, the greater part of it flowing through the series coils and across the arc. However, a very small portion flows through the shunt coil, and the amount of this current depends on the length of the arc. As the arc lengthens, due to the consumption of the carbons, the current in the shunt coil increases and causes the lamp to feed. The current flows in at the positive terminal, flows through the two coils as described, and out at the negative terminal and on to the next lamp of the series, passing through all the lamps on the circuit, and finally reaching the negative terminal of the dynamo. There are many different types of arc lamps, and the actual path of the current depends considerably on the design. In some lamps the fine wire coil is shunted across the lamp terminals. In others it is shunted across the carbons, the latter being the usual practice. For a good description of arc lamps we would refer you to the second volume of Crocker's Electric Lighting.

(41) Not long ago I set up three cells, having "fire alarm" pattern zincs and carbons hung in the center, using a saturated solution of sal ammoniac. In about two months' time, two of the three cells had a snow-white substance crusted all over the zincs and carbons, nearly filling the upper part of the jar. This substance also forms in Sampson cells that we are using in recorder work. Can you tell me how to stop the formation of this substance and why it formed in only two of the three cells mentioned? W. A. D. P., Orizaba, Mex.

ANS.—This white substance is formed in the following manner: The sal ammoniac solution, by capilliary attraction, creeps up over the portions of the jar and electrodes above the solution, the water in the thin film of this solution evaporates, leaving the sal ammoniac as a white salt. This will continue almost indefinitely under certain conditions, thus covering all exposed portions of the cell. It may usually be prevented by using a jar, zinc and carbon electrodes that are thoroughly coated with paraffin, or wax, above the surface of the solution in the jar, and by placing the cells in a cool, dry place. This creeping of the salts, as it is commonly termed, will not usually take place over a surface that is thoroughly coated with paraffin or wax. A poor quality of sal ammoniac should never be used, and it should never be dissolved in lead vessels. It is best to use an almost saturated solution of sal ammoniac, but an over saturated solution is as bad as too little sal ammoniac. Care should be taken not to allow any of the solution to get on the cover or upper portion of the electrodes, otherwise the crystallization and creeping of the salts is very apt to produce a short circuit and the cell exhausts itself on an apparently open circuit. We are unable to say, without personal examination of the cells, exactly why the salts were formed on two and not on the third cell.

***

(42) In your Mechanics' Pocket Memoranda you give a table showing the diameter of all wires. This divided by $\frac{1}{1000}$ and multiplied by 1,000 would give the diameter in mils. For example No. 0000 wire has a diameter of .460 inch or $.460 \times 1,000 = 460$ mils diameter. Will you kindly advise me if this is the correct solution, and if so, why is it that the table showing the diameter of No. 4 wire gives .2043, and diameter in mils, 204.310, when according to the above it should be 204.300? If I am not right will you kindly show in a problem how the mils are obtained when you have the diameter in inches?

R. E. D., Ft. Hamilton, N. Y.

ANS.—The diameter in mils is obtained by multiplying the diameter in inches by 1,000 as you state, because 1 mil is one one-thousandths of an inch. The difference which you note in connection with the No. 4 wire is simply due to the fact that the last decimal figure has been dropped in giving the diameter of the wire because it would be of no practical use to give the diameter to hundred-thousands of an inch. Some wire tables give the diameter in mils, while others give the diameter in decimals of an inch.

***

(43) Would you kindly give me the name of some good book on shop testing of alternating-current machinery, showing for what this class of machinery is tested and and the methods of testing? Three phase testing is particularly desired.

W. C. H., Columbus, Ohio.

ANS.—We do not know of any book relating particularly to the shop testing of alternating-current machinery. The tests made on these machines are, in general, much the same as those made on direct-current machines. All resistances are carefully measured, and checked up, and the heating of the machine under a continuous full load is also measured, preferably to noting the rise in resistance due to the heating. One of the most important tests in connection with an alternator is the test for voltage regulation. In this test, the machine is run with constant field excitation and the voltage measured under different loads. You will find much valuable information relating to shop testing in general in "Shop and Road Testing of Dynamos and Motors," by Parham and Shedd, although this book does not relate particularly to alternating-current machinery. The price of the book is $2.00, Technical Supply Co., Scranton, Pa.

MISCELLANEOUS

(44) (*a*) I have a formula which reads as follows: ½% solution of red prussiate of potash mixed with an equal volume of a ½% solution of ferric chloride. I wish to make ½ gallon of this solution, that is 1 quart of each. Please explain how to figure the amount of water to use. (*b*) What is mastic which is sometimes used in connection with asphalt? (*c*) Can copper wire be used as an anode in copper plating?

H. W. B., Pueblo, Mexico.

ANS.—(*a*) A quart of water weighs about 32 oz. or 15,360 grains troy. In order to make up your solution, you have to measure out 1 quart of water, add 76.8 grains by weight of red prussiate of potash, and to another quart of water add 76.8 grains of ferric chloride, allow the compounds to dissolve and then mix. (*b*) Mastic, used in

connection with asphalt, is a mixture of bituminous limestone with materials such as maltha or mineral pitch and petroleum. The three are fluxed together by heat and constant stirring until a uniform mass is obtained. The heat is kept at about 300° F., and when the mastic is a thoroughly homogeneous mass, it is poured into molds to cool. Maltha is obtained from bituminous rock by crushing and boiling it in water. At the melting point of asphalt it separates from the rock and floats on the surface of the water, from which it is removed and refined again by a second boiling in water. The residuum from the second refining is what is used for making mastic. Mastic contains approximately 20% of bitumen. The oil and maltha are termed the flux. 1 part of this flux is usually mixed with 9 parts asphalt rock carrying 12% bitumen. (*c*) Yes, copper wire can be used, the only objection is that the wire might eat away faster in some places than others, and is more likely to fall apart than a plate, because even if the latter has a hole eaten through, the surrounding parts will hold it together.

***

(45) (*a*) On a brick pavement where the bricks are set edgewise on a bed of sand, is it better to fill the cracks between the bricks with sand or with cement. It seems to me that cement will hold the bricks together while sand will expand on freezing. (*b*) Why does wet sand pack better than dry sand? (*c*) What would be the side pressure in proportion to the bottom pressure in a round tank 85 feet in diameter and 30 feet deep?

A. Y., Eau Claire, Wis.

ANS.—(*a*) We are inclined to think that the use of cement gives better results, though we are doubtful if the results are enough better to pay for the additional cost over the use of sand. (*b*) Simply because the moisture it contains causes the particles to adhere to each other. (*c*) The pressure is due solely to the height of the level surface of the water above the point at which the pressure is considered, and is equal to .43302 lb. per sq. in. for every foot of head or 62.355 lb. per sq. ft. for every foot of head (at 62° F.). The pressure per square inch is equal in all directions downwards, upwards, or sideways, and is independent of the shape of the vessel. So you see the pressure on the side of the vessel varies with the distance from the surface of the liquid, increasing as the distance from the surface increases.

***

(46) (*a*) Please give the correct French and German equivalents for the following expressions: 1, taps and dies; 2, screw plate; 3, taper tap; 4, plug tap; 5, bottoming tap; 6, tap wrench; 7, twist drill; 8, taper shank drill; 9, hand reamer; 10, bolts and nuts; 11, tool post. (*b*) Do you know of any method of preventing perspiration forming on hands and thus moistening tools and instruments so that they will rust?

C. S. B., Bennington, Vt.

ANS.—(*a*) 1, Taraud, das Schraubenschneidzeug; 2, Fillière, das Schraubenschneideisen; 3, Taraud conique, der konische Gewindebohrer, or Mutter bohrer; 4, Second taraud, der Loch Gewindebohrer, or der erste bohrer; 5, Dernier taraud, der Original bohrer, or Backen bohrer, letzte bohrer; 6, Manche de taraud, das Windeeisen; 7, Meche en spirale, der Spiralbohrer; 8, Meche à bout conique, der bohrer mit konischer Angel; 9, Equarrissoir a main, die Hand reibahle; 10, Boulons et écrons, Bolzen und Muttern; 11, Support, der Support. (*b*) No; wipe the instruments dry with a piece of chamois skin or any dry cloth when through using and they will not rust.

***

(47) (*a*) How do you treat aluminum castings to obtain the frosted effect sometimes seen on match safes, pin trays, etc.? (*b*) How do you treat yellow brass or copper to get the antique finish? (*c*) How do you oxidize these metals? (*d*) Name some book on the subject of finishing various metals, and also a book on electric plating and electric metallurgy.

H. D. B., Penacock, N. H.

ANS.—(*a*) Use a bristle brush and fine sharp sand. (*b*) Wash in dilute acetic acid and expose to the fumes of ammonia. Repeat alternately until the desired color is obtained. (*c*) Immerse the article in a solution of 2 ounces nitrate of iron and 2 ounces hyposulphite of soda to 1 pint of water until the desired shade of oxidization is reached; then wash, dry, and brush. (*d*) The Scientific American Cyclopedia of Receipts, Notes, and Queries. Price $5.00. This can be obtained from the Technical Supply Co., Scranton, Pa.

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(48) (*a*) In trying to make a number of cheap badges of a composition of lead and block tin in a plaster-paris mold, I find that the metal takes no impression or only a slight one at the edges. Kindly tell me how it may be done successfully. The badges are for free distribution and so must be as inexpensive as possible. (*b*) When were electric cars first successfully operated in America? J. A. B., Denver, Col.

ANS.—(*a*) We think that you are pouring the metal too cold. To get a sharp impression, the mold must be free from moisture and the metal quite hot—almost showing a dark red in a darkened room. (*b*) The first electric street railway operated commercially was in Cleveland. It was opened July 27, 1884.

SCIENCE AND INDUSTRY

Vol. VII | March, 1902 | No. 3

ARITHMETIC OF THE SAFETY VALVE

CHAS J. MASON

DEAD WEIGHT, SPRING, AND WEIGHTED VALVES—THE PRINCIPLE OF THE LEVER—EQUALITY OF MOMENTS—EXAMPLES SHOWING THE RELATION WHICH THE FACTORS BEAR TO EACH OTHER

AMONG the most perplexing questions encountered by the young steam engineer, are those concerning the safety valve in its different phases.

It is of great importance that the subject be understood, if for no other reason than that at all examinations for engineer's certificates, questions concerning it are asked in one form or another, and sometimes the failure to answer the question correctly causes the candidate to be put back for a certain period of time, before he can again present himself for another examination.

Not that the safety valve question is really difficult, for it is not; failure results more frequently because of too much confidence being placed in the committing of a written rule to memory, instead of inquiring as to *why* the rule is phrased as it is. It might be argued, what difference does it make whether the student understands *how* the rule is formed, as long as he has the rule to work with; that the men who formulated the rule did the thinking and reasoning, and all that the student has to do is to apply the rule when it is required of him.

If the sole purpose of an examination was simply to draw out answers to a given set of questions, then the foregoing reasoning might be true; but as the object of an examination is to discover how much the candidate really knows of the subjects under consideration—not merely giving a catechism style of answer, and applying a committed-to-memory rule—the arguments referred to do not hold good. A child may be taught that 5 and 2 are 7, and when asked the question will give the correct answer, but reverse the numbers and ask him how much 2 and 5 are, and he will falter; and even if he should give the correct answer, it will be given hesitatingly, because he has not learned the problem in that form, and the new position of the figures confuses him. So it is with men who study in that way, with the one object in view of obtaining a certificate; they are almost sure to stumble and fall.

So it would appear that in all studies the best results can only be obtained by a thorough searching into all the material concerned, and reasoning out each step from beginning to end. There is an aphorism which says: "Study is like the Heaven's glorious sun, that will not be deep searched with saucy looks." The engineer has many things to "deep search" which will require serious thought rather than a good memory. The safety valve is one of these problems, and it is the purpose of this article to try to make clear each and every step in the various calculations

employed As a general rule, textbooks do not give more than the method of making such calculations, with an example or two, illustrating the given formula or written rule. Not much space is devoted to the subject, because it is assumed that the student will dig into the details himself, after having been given a start. Some students do so, but there are many more who do not, because the start given is not sufficient to enable them to continue in the right direction. Again, there may be nothing in the textbook to lead them to think that anything further than that treated of is of any value, or even exists.

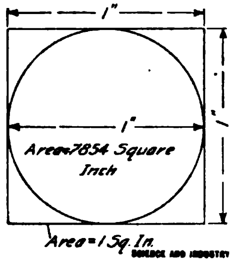


FIG. 1

Let us then look into all that concerns the problem. Every man who has been engaged in a steam plant for any length of time knows what a safety valve is, and what it is for. He may or may not know that there are three types of safety valves in use, viz.: the dead weight, the spring loaded, and the weight and lever type.

The dead-weight type—as the name implies—is that in which the weight holding the valve closed, is placed directly on top of the valve. The total weight is made up of a number of separate weights which may be of iron or lead. These weights are circular in form with a central hole, through which the valve stem protrudes, it being long enough to receive the required number. The whole thing is encased in a cylindrical attachment, which also regulates the height to which the valve shall lift.

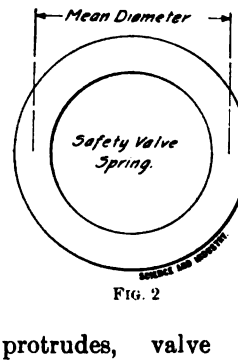


FIG. 2

Spring-loaded valves are those which are held to their seats by a spiral spring, which is subjected to compression.

The weight and lever type of safety valve is that in which the weight is applied to the valve through the medium of a fulcrum and lever.

The upward force of the steam at a given pressure, against the area of the valve, must be balanced by a downward force, the method of finding such force depending upon the type of valve to be considered.

In the dead-weight type, the actual downward force will be the same as the upward force, and it is found as follows: Suppose we have a valve which is 3 inches in diameter, and is to be loaded to balance a pressure of 60 lb. per sq. in., as per boiler gauge.

We first find the area of the valve—the number of square inches it contains—thus,

$$\text{area} = D^2 \times .7854,$$

where $D =$ the diameter of valve and $.7854 =$ a constant. See Fig. 1.

Our valve therefore contains $3 \times 3 \times .7854 = 7.0686$ sq. in.

Upon each square inch there is a pressure of 60 pounds, as indicated by the gauge.

Therefore, the total upward pressure will be $7.0686 \times 60 = 424.116$ lb.

The required weight upon the top side of the valve will therefore be **424.116**, minus the weight of the valve and stem, which has to be taken into account. The friction of the moving parts has not (and will not in this article) been taken into consideration, because it is an unknown quantity, and

difficult to determine; but it may be said, that it is so small that even if it were known, it would not materially affect the calculation, and so it is never sought.

While no dependence is placed upon figures in setting a spring-loaded valve—the method being to actually apply pressure and adjust the spring accordingly—yet there are rules in existence which at least approximate results determined by practice. For the benefit of those who may not have these formulas, they are given herewith:

$$\frac{8{,}000s^3}{d} = \text{whole pressure on the valve},$$

where s = the thickness of steel of which the spring is made, and d = the mean diameter of the spring or the diameter from center to center. See Fig. 2.

To illustrate this, let us take an example: A safety valve 5 inches diameter has a spiral spring 4 inches outside diameter, made of $\frac{3}{4}$-inch round steel; what will be the pressure per sq. in.?

Total weight $= \dfrac{8{,}000 \times .75^3}{3.25} =$ 1,038.46 lb.

Area of valve $= 5^2 \times .7854 = 19.635$ sq. in.

Pressure per sq. in. $= \dfrac{1{,}038.46}{19.635} =$ 52.88 lb.

The foregoing is the fundamental problem to connect the loading of the spring valve with that of a direct weighted valve, and from it may be found the proper thickness of steel, and the proper diameter of the spring, by a transposition of the formula. The constant 8,000 is used for round steel springs, while for square steel springs 11,000 is used.

Should the diameter of the spring be required, the formula would be transposed; thus,

$$d = \frac{8{,}000s^3}{w},$$

where d = the mean diameter of the spring, s = the thickness of the steel, and w = the whole weight on the valve.

If the thickness of the steel be required, the formula becomes

$$s = \left(\frac{w\,d}{8{,}000}\right)^{\frac{1}{3}}.$$

To find what compression should be given a spring to produce a given effect, the following formula is given:

$$\frac{w \times d^3}{s^4 \times G} \times n = \text{total compression},$$

where w = whole weight on the valve in pounds; d = mean diameter of the spring; s = thickness of the steel in *sixteenths* of an inch; and G is a constant. $G = 30$ for square steel and 22.8 for round steel; and n = the number of coils of the spring.

Although we have so far been considering calculations connected with dead weight and spring-loaded valves, the main feature of the article is that concerning methods of calculation applied to the lever and weight safety valve, because it is this type which is usually treated of in examinations.

As the downward force is effected through the medium of a lever in this type of valve, it will be necessary to first understand the principle of the lever before we can proceed with the regular calculations, as suggested in the usual rules relating to the subject. A knowledge of the principle of the lever preceded the application of its use to the safety valve, and by its use large weights are dispensed with.

Levers are of three kinds, as shown in Fig. 3:

1. When the fulcrum is between the force and the weight.

2. When the weight is between the fulcrum and the force.

3. When the force is between the fulcrum and the weight.

In all three the principle is the same and that is, *the force multiplied by its*

distance from the fulcrum is equal to the weight multiplied by its distance from the fulcrum. From this we see that there are three points to be considered: The fulcrum or point about which the lever

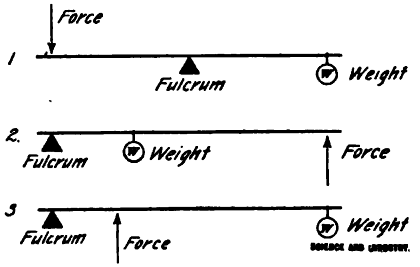


FIG. 3

turns; the point where the force is applied; the point where the weight is applied.

In this connection it is usual to employ the term *power* instead of force, although strictly speaking, it is not right to do so.

The lever of the *third kind* is the one that is applied to safety valves.

When the total upward force is known, as found by calculations already illustrated, the amount of weight to place at a given distance on the lever, or, the distance at which a given weight shall be placed, is determined by applying the rule of the principle of the lever.

But we also must take into consideration the fact that the lever itself exerts a certain amount of force against the valve, tending to keep it closed. If the lever were long enough no other weights would be required at all. The force exerted by the lever is stated as the *effective weight of the lever.*

The effective weight of the lever depends upon its actual weight (that found by weighing in scales), the location of its center of gravity, and the distance the force is to be applied (in other words, the center of the valve) from the fulcrum.

The weight of the lever is found by weighing it.

The center of gravity is found by suspending it, or balancing it on a knife edge. If a lever were of equal cross-section throughout its entire length, the center of gravity would be at the center; but if it is a tapered lever, the center of gravity will be nearer the larger end.

To find the effective weight of a lever we proceed thus:

Multiply the actual weight by the distance of the center of gravity from the fulcrum, and divide by the distance from the fulcrum to the valve. For an example we have the following:

A lever is 20 inches long, weighs 2 pounds, the center of gravity is 10 inches from the fulcrum, and the valve is 4 inches from the fulcrum. What is the effective weight of this lever upon the valve? See Fig. 4.

$$\frac{2 \times 10}{4} = 5 \text{ lb. effective weight.}$$

From which we learn that the shorter the distance between the fulcrum and the valve, the greater will be the effective weight of the lever on the valve. This may be demonstrated in the following manner:

Suppose we take the lever we have

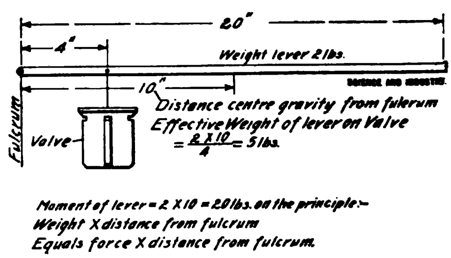


FIG. 4

just referred to and place it on two supports, as shown in Fig. 5. The support at the left representing the fulcrum, that at the right representing the valve. It is evident that as the

lever weighs 2 lb., each support must sustain one half, or 1 lb. Now, move the support at the right, under the central point of the lever, which is 10 inches from the fulcrum, and as that is the balancing point, the whole weight of the lever—2 lb.—is sustained by that support. The support representing the fulcrum might just as well be removed in this instance, as it does not affect the result. The support may be moved from right to left to any point, and the weights it sustains will be proportional to those found in the illustration.

At 20 inches it is 1 lb., at 10 inches 2 lb., at 5 inches 4 lb., at 1 inch it would be 5 times 4 or 20 lb. So, if at 1 inch, 20 lb. be exerted, at 4 inches one quarter of 20 lb., or 5 lb. will be exerted, as found before.

It is important therefore that these two points concerning the lever, as applied to the safety valve, be understood: The rule of the principle of the lever, which assumes the lever itself to have no weight; and, that in actual practice the lever has an effective weight. While these two calculations are separate and different in degree, they are essentially the same.

Besides the effective weight of the

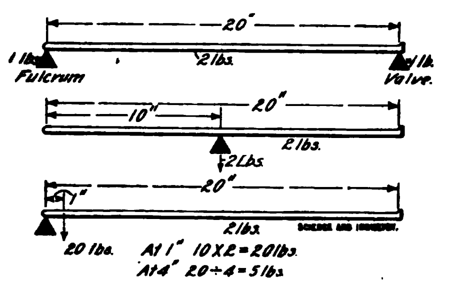


FIG. 5

lever in the calculation in a problem, we must make due allowance for the weight of the valve, and stem, if there be such.

To recapitulate; we have an upward force against the under side of the valve, which is to be balanced by the weight of the valve, the effective weight of the lever, and the weight of the weight, which is to be placed or hung upon the lever. This condition of affairs is graphically illustrated in the following form:

weight of the weight.	times.	distance of weight from fulcrum	plus.	weight of the lever.	times.	distance center of gravity is from the fulcrum.	plus.	weight of the valve.	times.	distance from the fulcrum.	equals.	pressure per sq. in. exerted.	times	area of valve.	times	distance of valve from fulcrum.
‖		‖		‖		‖		‖		‖		‖		‖		‖
W	$\times$	D	$+$	W'	$\times$	D'	$+$	w	$\times$	d	$=$	P	$\times$	A	$\times$	d

$$W\times D + W'\times D' + w\times d = P\times A\times d$$

The weight $\times$ distance from fulcrum $=$ the force $\times$ distance from fulcrum, the principle of the lever reiterated in full.

Some of the readers may think that they are being led into a problem which requires the use of algebra, because of the form of the foregoing statement; and, because they may not understand algebra, be inclined to discontinue a study of the question. The formula is called an algebraical formula, because letters are used to represent numbers; it is a simple arithmetical statement, embracing multiplication and addition, and during the operation of an actual problem in which numbers are substituted for the letters, division.

Now, by using this form, when given a problem concerning the safety valve, the unknown quantity—that is, the required answer—can be found, no matter how the question be put, or which of the factors is required. Let us try its operation.

As an example, we will use the following question, which is given in the same manner as in examinations. The given figures are used to illustrate the principles and application of the

formula only, no regard to correct proportions, weights, etc. being paid whatever, when looking at it from a mechanical standpoint.

A safety valve is 4 inches in diameter and weighs 5 lb.; the distance from the fulcrum to the valve is 4 inches, and the extreme length of the lever is 20 inches; the lever weighs 2 lb., and the center of gravity is at 10 inches from the fulcrum. The pressure to be balanced is 100 lb. per sq. in. What weight will be required at the end of the lever?

No matter what method may be employed to solve this kind of a question, it will be found of great assistance to the student to make and dimension a diagram, as shown in Fig. 6, for then the problem will be clearly seen and easily understood, much better than when expressed in words, as at first given.

By substituting the given numbers in our problem for the letters in the formula, we have:

$$W\times D+W'\times D'+w\times d=PA\,d$$
$$W\times 20+2\times 10+5\times 4=100\times 12.5664\times 4$$

Continuing,

$$W\times 20+20+20=5{,}026.56$$
$$W\times 20+40=5{,}026.56$$
$$20\ W=5{,}026.56-40$$

and $$W=\frac{4{,}986.56}{20}=249.328$$

The required weight is, therefore, 249.328 lb.

Suppose, now, that it is required to find the *weight of the lever*, the other figures remaining the same as in the foregoing example. We are aware that such a question would seldom or never be asked a candidate at an examination of steam engineers; and, indeed, such a question would be of no practical value. It is fair to assume, however, that were it given, comparatively few would be able to correctly answer it. A thorough understanding of the given formula will enable that, as well as any other question concerning the safety valve, to be worked out.

Again substituting figures for their relative letters, we have the following:

$$W\times D+W'\times D'+w\times d=PA\,d$$
$$249.328\times 20+W'\times 10+5\times 4=100\times 12.5664\times 4$$
$$4{,}986.56+W'\times 10+20=5{,}026.56$$
$$5{,}006.56+W'\times 10=5{,}026.56$$
$$10\ W'=5{,}026.56-5{,}006.56$$
$$10\ W'=20$$
$$W'=2.$$

Therefore the weight of the lever is 2 lb.

It will be seen that any factor to the left of the equation may be found in a similar manner and with as great ease.

To find an unknown quantity to the right of the equation, we proceed as follows:

Let us assume that the pressure per square inch is required:

$$W\times D+W'\times D'+w\times d=PA\,d$$
$$249.328\times 20+2\times 10+5\times 4=P\times 12.5664\times 4$$
$$4{,}986.56+20+20=P\times 50.2656$$
$$5{,}026.56=P\times 50.2656$$
$$5{,}026.56=P\ 50.2656$$
$$P=\frac{5{,}026.56}{50.2656}$$
$$P=100$$

which is the pressure per square inch as required.

If the pressure (100 lb.) is given, and it is required to find the *diameter* of the valve, the 5,026.56 would be divided by 400 (100×4), which gives 12.5664, the area of the valve, from which the diameter can be found as follows: $\frac{12.5664}{.7854}=16$, and the square root of $16=4$, which is the diameter of the valve in our problem.

By the use of this formula all confusion of ideas is avoided when a problem has to be solved. There is nothing to be committed to memory in the ordinary sense of the phrase, a simple understanding of the principle of the lever and its application to the safety valve being all that is required. Once this is known and understood, it would

be almost impossible to forget it, which cannot be said of something which has been learned by rote and committed to memory.

Should a student be taught one or two rules which he could apply to safety-valve problems—say the two usually given, viz.: (1) Finding the weight to place at a given distance; (2) finding the distance at which a given weight should be placed; he would not only be liable to forget such rules (because of non use), but if a problem were given him in any other form, or to find any other factor, he would be lost unless he were ingenious enough to manipulate the figures to gain the desired result. But this would cost more time than would an elementary study of the subject.

From the formula of equality of moments has originated the following table, which is the same principle, though of somewhat different form:

(1) $P \times S -$ effective weight of lever $\div L = W$;

(2) $P \times S -$ effective weight of lever $\div W = L$;

(3) $L \times W +$ effective weight of lever $\div S = P$;

(4) $L \times W +$ effective weight of lever $\div P = S$;

where, $P =$ power (area of valve $\times$ pressure per sq. in. minus weight of valve);
$S =$ short arm (distance from fulcrum to valve);
$L =$ long arm (distance from fulcrum to weight);
$W =$ the weight.

In cases 1 and 2 the weight of the valve is to be *subtracted* from P.

In cases 3 and 4 the weight of the valve is to be *added* to P.

The effective weight of the lever is here taken to mean, the product of its weight and the distance of its center of gravity from the fulcrum (equivalent to $W' \times D'$ in the first formula), and not that as found in the first part of this article. Now, there is this to be said about the apparent discrepancy of the two methods: In the first instance the effective weight depends upon the distance of the valve from the fulcrum, while in the second, this distance is taken care of elsewhere, as can be seen by a study of the formula. The two methods will give exactly the same results, when worked in their proper respective places.

It will be found, that by finding the effective weight of the lever by the first process, the proper method is to subtract it from P, together with the weight of the valve. Using the previous example, we will illustrate the two operations, using the table formula last given.

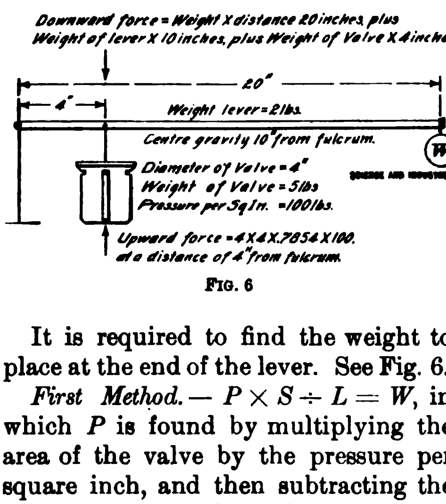


FIG. 6

It is required to find the weight to place at the end of the lever. See Fig. 6.

First Method. — $P \times S \div L = W$, in which P is found by multiplying the area of the valve by the pressure per square inch, and then subtracting the effective weight of the lever plus the weight of the valve. Then, 4 in. $\times$ 4 in. $= 16$ in. $\times .7854 = 12.5664$ area.

$12.5664 \times 100 = 1{,}256.64 =$ total upward force, pounds; weight of valve $= 5$ lb.; effective weight of lever $= \frac{2 \times 10}{4} = 5$ lb.; combined weights of valve and lever $= 5 + 5 = 10$ lb.; therefore, P in the formula $= 1{,}256.64$

$-10 = 1{,}246.64$, and following the formula, $\frac{1{,}246.64 \times 4}{20} = 249.328$ lb., weight required.

Second Method. — $P \times S$ — effective weight of lever $\div L = W$. In which P = area of valve multiplied by the pressure per sq. in. minus the weight of the valve.

Then, $4 \times 4 = 16$, and $16 \times .7854 = 12.5664$ area.

$12.5664 \times 100 = 1{,}256.64$ lb. = total upward force; weight of valve = 5 lb.

$1{,}256.64 - 5 = 1{,}251.64$, which is P in the formula.

$1{,}251.64 \times 4 = 5{,}006.56$, from which has to be subtracted the effective weight of lever.

Effective weight of lever $= 2 \times 10 = 20$ lb., and $5{,}006.56 - 20 = 4{,}986.56$.

$\frac{4{,}986.56}{20} = 249.328$ lb., which is the same as obtained by the first method. Both of these methods are correct in their respective places.

By this time it will have been seen, that the only factor in the safety-valve problem in which confusion is liable to arise, is that of the effective weight of the lever. But a study of the foregoing formulas and examples should make it clear to the student *how* and *why* the difference exists as shown; or in other words, the difference between the *isolated* case of the effective weight of a lever, and that in which its weight (together with other factors in a problem) is considered with reference to its distance from a central point, or fulcrum.

RAILWAY NOTES

On Saturday, February 15, a freight train, consisting of 30 heavily loaded cars, drawn by two engines, ran away on the mountain side above Scranton, Pa., and dashed down through the station at the rate of 60 miles per hour. Word of its coming was telegraphed ahead, and the yard was cleared as quickly as possible. A short distance past the station, however, the runaway dashed into a caboose, reducing it to splinters. A little further on a switch engine was overtaken, which brought the runaway to a standstill. All three engines and a number of cars were wrecked and three men were seriously injured.

The aggregate length of railway mileage in the United States, including tracks of all kinds, is about 260,000 miles.

There are about 40,000 locomotives in operation, while the number of cars reaches 1,500,000.

The railways of this country employ over a million persons.

The compensation of employes of railways represents on an average 60 per cent. of the operating expenses of the roads, and 39 per cent. of their gross earnings.

The number of passengers carried during the year ended June 30, 1901, as shown by the annual reports of railways, was 576,865,230.

The total number of casualties to persons on account of railway accidents during the year ending June 30, 1901, was 58,185. The aggregate number of persons killed in consequence of railway accidents during the year was 7,865, and the number injured was 50,320. Statistics show that in the course of thirteen years ending June 30, 1901, in consequence of railway accidents, 86,277 persons were killed and 469,027 persons were injured.

A BAD BREAKDOWN AND AN INGENIOUS TEMPORARY REPAIR

J N GERMAIN

IF EVER an engineer has to think quickly, it is when his engine "breaks down."

These "breakdowns" are many and of a variety to keep the best of men thinking.

The one to be considered occurred at about 2 o'clock P. M., and the shop

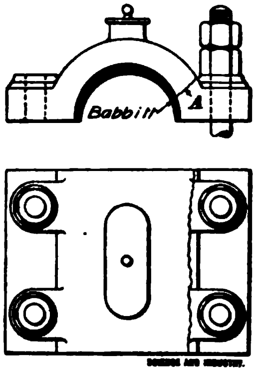


FIG. 1

had a number of jobs promised for the following day. The accident could not have happened at a more unfavorable time.

The engine was of the vertical type, having one bearing cast with the frame, the outboard bearing resting on the foundation. A heavy flywheel was located about midway on the crankshaft, with a 10-inch belt running over it, at an angle of 60°, to a jackshaft above.

The cap of the frame bearing fractured at *A*, Fig. 1, making a loud report. This report probably saved the engine from more serious injury, for the engineer on hearing the noise quickly turned off the steam.

Many theories were offered as to the probable cause of the break, but as it could not be definitely determined, and as the repair itself is the point of interest to us, we shall proceed to show how it was accomplished.

By referring to Fig. 1 we will see that the babbitt lining was not injured by the breaking of the casting. From the conditions of the break it was an easy matter to remove the lining intact.

After a few minutes' consultation the superintendent agreed to let the engineer proceed. The broken cap was sent to the iron foundry as a pattern for a new casting, at the same time adding material to the weak places.

The scheme for the repair was to cut out two hard maple blocks, carefully fitting the arcs *a b* and *c d*, Fig. 2, so as to insure an even bearing on the Babbitt metal.

Then, by taking two ordinary planer straps *e* and *f*, Fig. 2, the studs were long enough to allow one nut to be used, and, bolting the blocks down, the repair was completed.

This device was used for 4 days

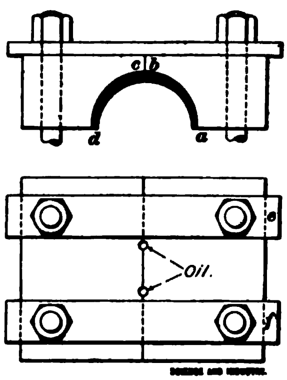
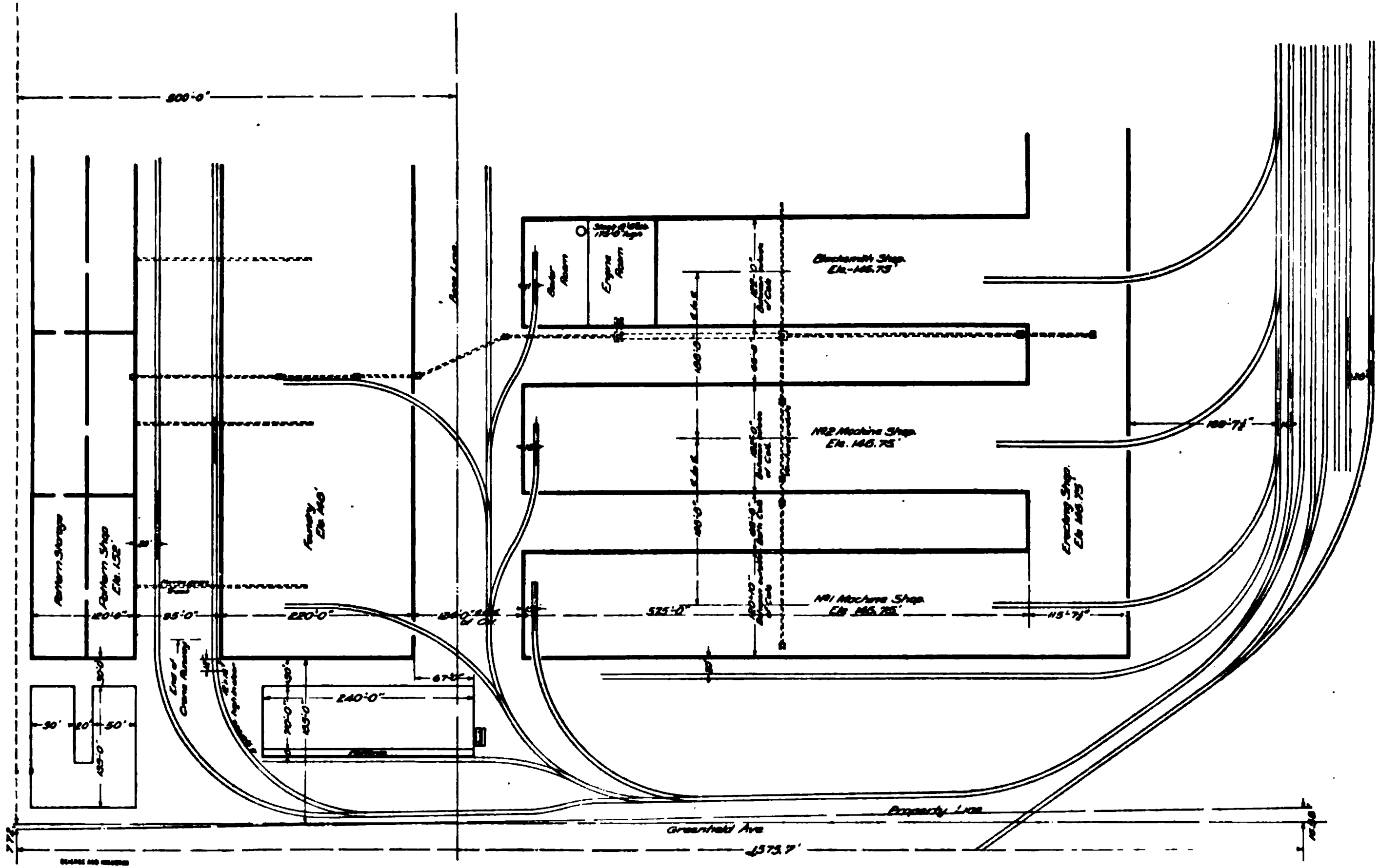


FIG. 2

and stood the work well. In the meantime the new casting was machined and babbitted. When all was ready the new cap was fitted at night.

The two blocks and planer straps that saved the firm so many dollars are on a shelf in the engine-room closet.



New Plant of the Allis-Chalmers Co., West Allis, Milwaukee, Wis.

A MODERN ENGINE-BUILDING PLANT

WE present herewith an outline of the new plant now being erected by the Allis-Chalmers Co. at West Allis, a suburb of Milwaukee, Wis. The Allis-Chalmers Co. was recently formed by the consolidation of the Edward P. Allis Co., of Milwaukee; the Fraser and Chalmers Co., and the Gates Iron Works, of Chicago, and the Dickson Mfg. Co. (exclusive of the locomotive works), of Scranton, Pa.

These plants were all crowded with work at the time of their consolidation, and, owing to the promising outlook for the future, the directors determined to erect a new plant, thereby largely increasing the capacity of the concern as a whole. Partly on account of the excellent location obtainable near Milwaukee, and partly because the largest plant of the company was already situated in that city, the present site, consisting of one hundred acres of nearly level ground, located about two miles west of the city limits, was chosen.

The ground is high and the soil consists of a firm clay, making an excellent foundation.

The accompanying illustration gives an idea of the general arrangement of the plant. The erecting shop, foundry, and pattern shop are parallel, starting near the southern property line and extending to the north. Branching out of the erecting shop and extending towards the foundry are bays 575 feet long and 120 feet wide, used for blacksmith and machine shops. The plan at present is to build the erecting shop, foundry, and pattern shop some 500 feet long and build three bays out from the erecting shop, two to be used for machine shops and one for a combination blacksmith shop and power house. As the business of the company increases and a larger plant is required, the erecting shop, foundry, and pattern shop, or any one of them, as necessity may require, may be extended to the north, ample ground being already provided, and more bays may be built out from the erecting shop.

Herein lies the great advantage of this arrangement. There is not a large engine-building plant in existence today, to our knowledge, where the arrangement of buildings is such that the product can be handled in the most expeditious and economical manner. Some of them were originally designed with this end in view, but as it became necessary to increase the size of the buildings, the ground was not available, and the result is that many plants exist today with maybe two or three pattern shops or foundries scattered around at different places and often widely separated, requiring a large amount of unnecessary labor in transporting patterns, castings, etc. from one building to another, and a consequent loss of time. In the plant under discussion, however, any or all of the buildings may be increased in size without changing in a particle the original plan. The raw material comes into the pattern shop, or foundry, as the case may be, at one end of the plant and comes out of the erecting shop a finished machine at the other end. Nothing moves backward. The buildings are all of steel construction work with brick curtain walls and slag roofs. The transportation facilities are ample, the plant being practically surrounded by the tracks of the Chicago, Milwaukee and St. Paul, and the Chicago and Northwestern Railways.

The pattern shop and foundry are connected by narrow-gauge tracks for transporting patterns into the foundry.

Electric traveling cranes run from the foundry between the bays to the erecting shop, while all of the shops are equipped with powerful cranes, that in the erecting shop having 60 feet clear under the hook. An ample supply of water is furnished by artesian wells. All of the machine tools, many of which are the largest and most powerful of their kind in existence, are to be operated by direct-connected motors, power being furnished by generators direct connected to Allis engines, located in the power house. At present writing work is progressing rapidly, the erecting shop and No. 1 machine shop being already finished. The original idea of the present arrangement was conceived by Mr. Edwin Reynolds, chief engineer of the company, and the design and construction of the plant are being carried out under his direction. Already numerous other industries are springing up in the immediate vicinity, and West Allis promises in a short time to become a thriving community. For the information contained in this article we are indebted to the courtesy of Mr. Edgar N. Dickson, purchasing agent of the company.

COMPENSATING VOLTMETERS

IN nearly all cases where electric lighting or power is supplied at a distance from the station, one of the most important requirements is that the voltage or pressure at the end of the line shall be kept constant. If this is not done, the lights and motors will give unsatisfactory service, and complaints will be numerous. There is always a certain loss of pressure in the line due to the resistance, and also, with alternating currents, to the self-induction of the line, so that, if the pressure at the distant end is to be kept constant, it follows that the pressure at the station must be raised as the load comes on. The question is, How is the station attendant to know how much to raise the station voltage in order to maintain a constant pressure at the other end?

With direct-current work, and also in many cases with alternating-current work, a common method is to run *pressure wires* back from the distributing center and connect these wires to the station voltmeter. Fig. 1 illustrates the scheme referred to. A dynamo supplies current to the distant center of distribution *c*, and the voltmeter *V*, instead of being connected to the dynamo, is connected to the pressure wires *a b*, which connect across the mains at the distributing center *c*. Now, the voltmeter requires but an exceedingly small current for its operation, so that there will be little or no drop in voltage in the lines *a b*, and the voltmeter will therefore indicate the pressure at the end of the line. Pressure wires are often of insulated iron wire, as the current to be carried is very small and iron answers the purpose quite well. However, copper wires are also largely used.

Pressure wires, therefore, give a simple means of getting at the voltage at the end of the line, and the switchboard attendant can regulate the dynamo voltage accordingly. But pressure wires are somewhat expensive to put up and maintain, and a number of compensating arrangements have been brought out for use in connection with the station voltmeter to make the latter indicate the voltage at the distant end without the necessity of running pressure wires back to the station. These

compensators have been used principally on alternating-current systems, and it is the purpose of this article to describe two of the types in most common use.

Fig. 2 shows the older type of Westinghouse compensator, and Fig. 3 shows the connections for it. The voltmeter shown in Fig. 3 is of the coil and plunger type, and is entirely separate from the compensator which is indicated in the left hand side of the diagram. *T* is a small transformer connected across the lines at the station and is used to step down the pressure for the voltmeter, as is ordinarily done with voltmeters used on high pressure alternating current. When the voltage at the end of the line is correct, the hand of the voltmeter points to the middle point of the scale. The compensator itself is a small transformer the primary of which is adjustable, and is inserted in series with the line. The terminals of the various sections are brought out to blocks *R*, *S*, *T*, etc., Fig. 2, and by means of a plug *h* any number of these sections may be cut into the circuit. The secondary of the compensator is connected to a small auxiliary coil *c*, Fig. 3, wound over the main voltmeter coil. By means of a small switch any desired number of secondary terms

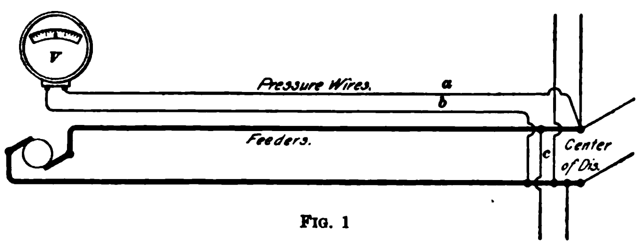


FIG. 1

can be included in series with coil *c*. Coil *c* is so connected that the current supplied to it from the secondary of the compensator flows around in an opposite direction to the current in the main coil *d*. In other words the current sent through the voltmeter by the compensator decreases the voltmeter reading, and the alternator voltage has to be increased to bring the voltmeter pointer back to the mid-position. By setting the plug in the primary and the switch

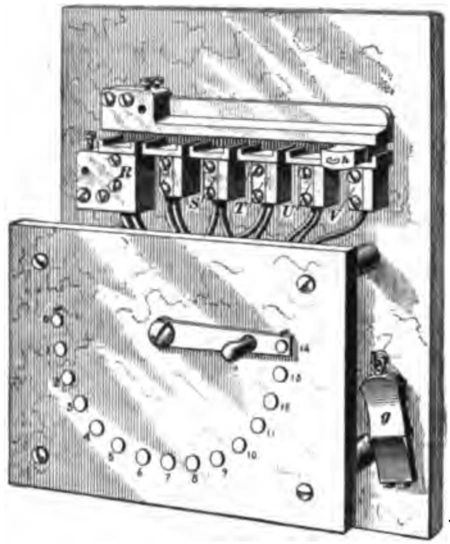


FIG. 2

in the secondary, according to the amount of drop that occurs in the line at full load, the voltmeter, if kept at its mid-position, will necessitate an increase in station pressure such that the drop in the line will be made up for. The pressure at the distant end will therefore remain constant. A table is furnished with the instrument showing the way in which the plug and secondary switch should be set for lines giving different amounts of loss. In changing the plug *h*, Fig. 2, the auxiliary plug *g* must first be inserted in the point desired before plug *h* is removed, otherwise the main circuit would be broken. This type of compensator is used in quite a number

of plants, and if properly adjusted, will give correct indications on lines of medium length, especially if the load is non-inductive as, for example, if lights constitute the bulk of the load. It must be understood that the com-

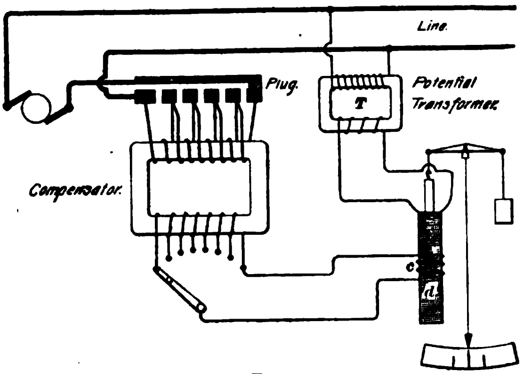


FIG. 3

pensator itself does not compensate for the drop in the line. It merely decreases the voltmeter reading by an amount proportional to the line loss, so that the switchboard attendant has to raise the voltage to bring the voltmeter back to the standard position.

A compensating voltmeter of the kind just described compensates only for the drop in the line due to the resistance of the line wire. On long lines, however, and especially in cases where the load is inductive, as for example a load of induction motors, the drop in the line may be considerably greater than that due to resistance alone. When two wires are strung parallel to each other they have more or less self-induction. For example in Fig. 4, if current is flowing in the wires A and B, magnetic lines, or whirls, will be set up around the lines as shown by the dotted circles. If the current is alternating, these lines will be constantly changing so that the number of lines threading through between the wires will vary. This changing of the magnetism threading the circuit will induce an E. M. F. in the circuit, and this counter E. M. F. makes an apparent increase in the resistance of the line, thus causing the line drop to be greater than it would otherwise be. The effects of line self-induction become quite noticeable on long transmission lines. If, in Fig. 4, the lines were run close alongside of each other there would be little self-induction, because few lines of force would thread between the wires. In practice, however, it is not possible to run the wires close together unless they are in the form of an insulated cable.

A compensator to give correct indications on a line having an appreciable self-induction must compensate not only for the drop due to line resistance, but also for the drop due to self-induction. This is accomplished by means of the Mershon compensator, the principle of which is illustrated by Fig. 5.

The principle on which this compensator operates is, briefly, as follows: The E. M. F. supplied at the end of the line is equal to the resultant difference between the E. M. F. generated and the E. M. F.'s necessary to overcome the resistance and self-induction. If, then, three E. M. F.'s are set up at the station that are proportional to the above named E. M. F.'s, and if these

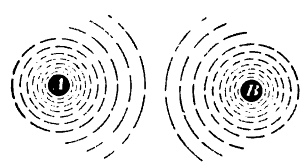


FIG. 4

E. M. F.'s are combined in the same way as the line E. M. F.'s, it is evident that their resultant E. M. F., indicated by the voltmeter, will be the E. M. F. at the end of the line. For example,

take the simple arrangement shown in Fig. 5 (*a*). The alternator *A* supplies current to the line, and *T'* is a small transformer, the secondary voltage of which is proportional to the generator voltage and is in phase or in step with it. If the voltmeter *V* were connected directly to *T'*, the indications of *V* would be proportional to the station voltage; but what is wanted is an indication of the voltage at the far end of the line, and in order to get this, the voltage of *T'* must be reduced by an amount equal to the resultant sum of the drops caused by the line resistance and self-induction. In order to accomplish this, an adjustable self induction *a* and resistance *b* are inserted in the circuit. The drop through *b* will be proportional to the resistance drop in the line and in phase with the line drop. The voltage across *a* will be proportional to and in phase with the drop due to line self-induction. From the way in which the connections are made it is easily seen that the voltage acting on *V* is a combination of the voltages of *T'*, *a*, and *b*. The voltage across *a* and *b* will increase as the current delivered to the line increases, and the voltmeter reading will therefore decrease as the load comes on, because the connections are made so that the pressures across *a* and *b* cut down the E. M. F. applied to *V*. The voltmeter will therefore indicate the voltage at the end of the line if *a* and *b* are properly adjusted.

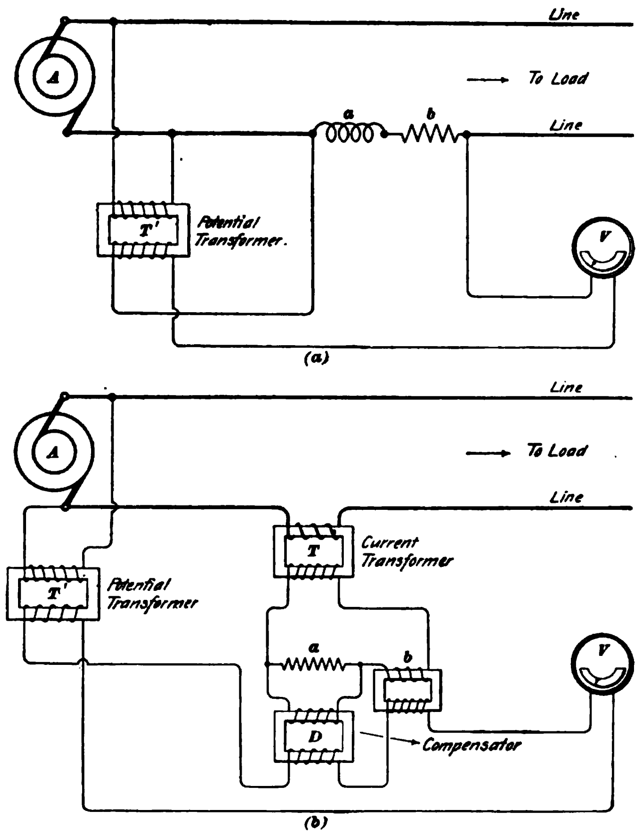


FIG. 5

The connections in Fig. 5 (*a*) are made as simple as possible in order to bring out the principle of operation. The actual connections are more like those shown in (*b*). *T'* is the potential transformer as before, and instead of inserting *a* and *b* directly in the line, as in (*a*), they are inserted in the secondary of a transformer *T*, the primary of which is in series with the line. The compensator proper consists of three parts, *a*, *b*, and *D*. *a* is the resistance as before, and *b* the inductance coil wound on an iron core, which also serves as a transformer core; *a* and *b* are connected in series, and the current supplied from the sec-

ondary of T passes through them. The E. M. F. across a is therefore in step with and proportional to the resistance drop in the line, while that across b is proportional to the drop due to self-induction. D is a small transformer in shunt with a, hence its secondary E. M. F. is proportional to the drop across a; b is also provided with a secondary coil which gives an E. M. F. proportional to the voltage across b. The voltage which actuates the voltmeter V is a combination of the three pressures of T', a, and b, and a and b are so adjusted that V indicates the pressure at the end of the line.

D, b, and a are in one piece of apparatus, and terminals from the secondaries of D and b are brought out to multipoint switches. The number of turns in each may be thus adjusted to suit different conditions so that the station voltmeter will indicate the voltage at the distant end no matter what load the line may be carrying.

USEFUL FORMULAS—II

JOSEPH E. LEWIS, S. B., JUNIOR MEMBER A. S. M. E.

For Calculating Condensing Surface in Condensers, $S = \frac{WL}{ck(T-t)}$

FORMULAS may be divided into two general classes, namely: Logical formulas, that is, those based upon an exact mathematical analysis, and empirical, or experimental, formulas, which are based upon experimental work.

Logical formulas are usually applied to a wide range of problems having the same theoretical basis, but under widely different practical conditions. Take, for example, the formula $t = \frac{pr}{s}$, considered in the last number of this series. Every case to which it was applied was a separate problem capable of being solved correctly only in the light of the practical conditions involved. This is always true in the application of theory, for theory and practice are but two parts of the same thing.

Theory must be based upon practice, and practice must be based upon theory. Theory classifies and arranges the results of practice and draws conclusions from them. Practice acts upon the conclusions of theory and produces new and better results. The complete theory embraces every practical condition and every practical result. The perfect practice is that which is based upon the complete theory. It is readily seen that one is no less difficult of attainment than the other. These can never clash, but must always harmonize. That theory and practice, as we find them, do often appear to disagree, is due to the incompleteness of one or the other, and often of both.

Let the practical man, therefore, not despise theory since it may serve him well and teach him not a little, and let the "theoretical man" examine carefully the results of practice and give full weight to the voice of experience. Our rules and formulas are not worth the paper they are written upon unless interpreted in the light of experience; and on the other hand it is sometimes almost pathetic to see the possibilities of a life-long experience unrealized through lack of technical training.

The empirical, or experimental, formula, frequently called a "rule of thumb," being the result of experiment applies strictly within the limits of the experimental data from which it is deduced, and cannot be safely applied

beyond these limits. This class of formulas are usually applied to the solution of problems, which, from their nature, do not admit of an exact logical solution, and they give only approximate results.

A good illustration of an empirical formula is that proposed by Witham, in Steam Engine Design, p. 283, also Trans. A. S. M. E. ix, 431, for calculating the condensing surface in condensers. It is as follows: $S = \frac{W L}{c k (T - t)}$, in which S = condensing surface in square feet; T = temperature in degrees Fahrenheit of steam at the pressure indicated by the vacuum gauge; t = mean temperature of the circulating water, or the arithmetical mean of the initial and final temperatures; L = latent heat of saturated steam at temperature T (see Steam Tables); k = perfect conductivity of the metal, or the number of heat units transmitted per square foot of tubular condensing surface per hour under the most perfect conditions for a difference of 1 degree between the water and steam surfaces; c is a fraction denoting the efficiency of the condensing surface, which is never in practice equal to its perfect conductivity; and W = the number of pounds of steam condensed per hour.

We have called this an empirical formula, and we mean that it is based upon experimental results. It must be remembered, however, that our methods of obtaining practical results are never quite free from theory; for when we begin to think we begin to theorize. Practice is dependent upon the memory alone; theory upon the understanding, or reason; and just as soon as we begin to reason we become theorists. The advantage of technical training lies in helping a man to reason correctly rather than in crowding his memory with mere facts. He must acquire the facts pretty largely by experience. And so the empirical formula under consideration is the result of theory to a certain extent. Let us examine it a little.

The expression $\frac{W L}{c k (T - t)}$ represents the number of square feet of heating surface required in a condenser under the conditions represented by the various letters W, L, etc. Now what do these letters stand for? $W L$ equals the total number of heat units (B. T. U.) given up by the steam in 1 hour in condensing, since L is the latent heat of 1 pound, and W is the number of pounds per hour. $c k$ equals the number of heat units that 1 square foot of surface will transmit in 1 hour for each degree difference of temperature between the steam side and the water side. $T - t$ equals the actual number of degrees difference; therefore, $c k$ multiplied by $T - t$, or $c k \ (T - t)$ equals the whole number of heat units transmitted per hour per square foot of surface. Now, if we divide the total number of heat units to be transmitted $(W L)$ by the whole number transmitted per square foot, $c k (T - t)$, our result is the number of square feet required to do the work. This result will, however, be only an approximation more or less accurate, depending upon the reliability of the experimental terms employed.

W may be determined by weighing or measuring the condensed steam, or the feedwater, where it all passes to the condenser. T and L may be found in Tables of Properties of Saturated Steam corresponding with the absolute pressure as indicated by the vacuum gauge, or T may be taken direct with a suitably placed thermometer. t is somewhat uncertain, however; at best it is only an average value, being the arithmetical mean between the initial and final temperatures of the cooling water.

That is to say, if the water enters at 60° by the thermometer and leaves at 100°, the value of t is taken as $\frac{60+100}{2}=80°$.

k is the result of experiment, and the values found by Mr. Isherwood, Engineer-in-Chief U. S. N., in 1867, are usually employed. He found that under the most perfect experimental conditions 1 square foot of copper surface would transmit 642 heat units per hour per degree difference in temperature between the steam and water sides. The result for brass was 557, and for wrought iron 374. It will be seen that if the conductivity of copper be taken as unity, that of brass is 87%, and that of wrought iron 58%. The factor c is the result of careful tests by Loring and Emery on the U. S. S. Dallas, and equals 0.323. Therefore, ck for copper is 207; for brass, 180; for wrought iron, 121.

To illustrate the use of the formula: Find the surface for a condenser to take care of a 500 H. P. compound engine running on 15 pounds of steam per H. P. per hour. In this case, $W=7,500$ pounds. Let the vacuum be 25 inches, and let the tubes be of brass. 25 inches by the vacuum gauge is equal to 2.45 lb. absolute $\left(\frac{5\times 14.7}{30}=2.45\right)$ since 30 inches is a perfect vacuum. Referring to the Steam Tables (see Peabody's Tables of the Properties of Saturated Steam), the temperature corresponding to this pressure is $134°=T$, and L (latent heat of vaporization) equals 1,021, nearly. $ck=180$. Now, assume that the cooling water enters at 50° and leaves at 100°, then $t=75°$ $\left(\frac{50+100}{2}=75\right)$.

Substituting the values above determined in the formula, we have $S=\frac{7,500\times 1,021}{180(134-75)}=\frac{7,657,500}{10,620}=721$ square feet, or approximately 1 square foot for $10\frac{1}{2}$ pounds of steam. For copper tubes the result would be $S=\frac{7,500\times 1,021}{207(134-75)}=627$ square feet, or about 1 square foot for 12 pounds of steam. The above results are reliable under usual conditions.

The same formula may be used for calculating the surface of feedwater heaters. The results of experience show that the value, $c=.323$, is applicable in the case of the water-tube type of heater where the water circulates rapidly over the heating surface, say from 100 to 200 feet per minute, as in the common form of coil heater, such as the American or National. Therefore, the values of ck already proposed may be used. For water-tube heaters, such as the Goubert or Wainwright, having larger area of flow and correspondingly slower velocity of the water, the surface should be increased by 10 to 25%; and for steam tube heaters like the Berryman, by 25% or more. The reason of this is that the slower the velocity of the water over the surfaces, the less the efficiency in transmitting heat.

We must modify the formula slightly as follows: In place of L substitute D, the difference between the initial and final temperatures of the feedwater, or the number of heat units added to it. The other terms will remain the same, W equaling the number of pounds of feedwater per hour. Then WD equals the total number of heat units taken up by the feedwater per hour, and $ck(T-t)$ equals the number transmitted by 1 square foot of surface per hour, so that $\frac{WD}{ck(T-t)}$ equals the number of square feet of surface required.

Assume a 300 H. P. boiler plant. $W=30\times 300=9,000$ lb. per hour.

Let the water be heated from 50° to 212°. $D = 212° - 50° = 162°$.

Suppose the heater to take steam from a non-condensing engine; then $T = 212$, $t = 50 + \frac{162}{2} = 131$, and $T - t = 212 - 131 = 81$. For copper coils: $S = \frac{9{,}000 \times 162}{207 \times 81} = 87$ square feet, or 42 square inches per horsepower. For brass coils: $S = \frac{9{,}000 \times 162}{180 \times 81} = 100$ square feet, or $\frac{1}{3}$ square foot per horsepower. For wrought iron: $S = \frac{9{,}000 \times 162}{120 \times 81} = 150$ square feet, or $\frac{1}{2}$ square foot per horsepower. Bear in mind that these results are for the coil type of heater, and should be increased for other types, as previously stated.

Now let us suppose that in the same 300 H. P. plant the heater takes steam from a condensing engine, being placed between the low-pressure cylinder and the condenser, and working under about 26 inches vacuum. Then $T = 125°$, $D = 125 - 50 = 75$, $t = 50 + \frac{75}{2} = 87\frac{1}{2}$, and $T - t = 125 - 87\frac{1}{2} = 37\frac{1}{2}$.

For copper coils:

$$S = \frac{9{,}000 \times 75}{207 \times 37\frac{1}{2}} = 87 \text{ square feet.}$$

For brass coils:

$$S = \frac{9{,}000 \times 75}{180 \times 37\frac{1}{2}} = 100 \text{ square feet.}$$

For wrought-iron coils:

$$S = \frac{9{,}000 \times 75}{120 \times 37\frac{1}{2}} = 150 \text{ square feet.}$$

Notice that the amount of surface is the same as in the previous case; that is to say, when the water is to be heated to the same temperature as the steam, the amount of surface required is independent of the temperatures involved, and varies only with the amount of feedwater. The above statement is not strictly true, but it is sufficiently correct within the limits of ordinary practice to which the formula applies.

A quick rule, then, for computing heating surface in feedwater heaters is to divide the number of pounds of feedwater per hour by 100 for copper, by 90 for brass, and by 60 for wrought iron. This gives 90 square feet, 100 square feet, and 150 square feet, respectively, in the above cases. It applies, of course, only where the water is to be heated to practically the temperature of the steam, and where the steam supply is abundant.

If it is desired in the first case to heat the water to only 200 degrees, we should figure as follows: $D = 200 - 50 = 150$, $t = 50 + \frac{150}{2} = 125$, and $T - t = 212 - 125 = 87$.

Then, for copper,

$$S = \frac{9{,}000 \times 150}{207 \times 87} = 75 \text{ square feet;}$$

For brass,

$$S = \frac{9{,}000 \times 150}{180 \times 87} = 86 \text{ square feet;}$$

For wrought iron,

$$S = \frac{9{,}000 \times 150}{120 \times 87} = 129 \text{ square feet.}$$

This form of computation may also be used for computing the surface for heating water with live steam, but the results will, in general, be larger than required. At all events the surface figured in this way will be ample, since the absence of grease, which cuts down the efficiency of an exhaust heater, renders the live steam heater correspondingly more efficient. It must be remembered that T is always the temperature corresponding to the pressure of the steam used for heating. Thus, if live steam at 80 pounds is used, $T = 323°$ F.

VENTILATING APPARATUS

E T CHILD

A Few Factors for the Determination of Size of Apparatus for Ventilating Buildings

IN designing a ventilating apparatus, the primary factor to be considered is the amount of air which is to be moved in a given time. This must necessarily depend upon the character of the building to be ventilated, as well as the number of occupants, and the relative space which is allowed per occupant; a greater amount of air per person being required in relatively small rooms than in those where the volume per occupant is extremely large. The factor of lighting also is important, as gas necessitates a certain amount of air, while electricity has no effect on the condition of the atmosphere.

According to John S. Billings, the following factors should be allowed for various classes of buildings:

Class of Building	*Cu. Ft. Per Hour*
Hospitals	3,600 per bed.
Legislative and assembly halls	3,600 per seat.
Barracks, bed rooms, and workshops	3,600 per person.
Schools and churches	2,400 per person.
Theaters and halls	2,000 per person.
Office rooms	1,800 per person.
Dining rooms	1,800 per person.

The general standard which has been adopted for schools, halls of audience, and similar buildings, is 1,800 cu. ft. of air per hour per person. There are, however, many instances where the number of occupants is a matter of great uncertainty, and it is often absolutely impossible to judge the probable requirements. This is particularly true in the case of office buildings and factories.

For this reason it is found advisable to decide upon a certain specific change of air for the whole or various parts of a building, and thus determine the requisite air supply. Often various parts of the same building must be treated in an entirely different manner; as for instance in a school building, the corridors are seldom allowed more than half as much ventilation as the school rooms.

To show more clearly the volume of air required for different air changes, a chart has been plotted (see Fig. 1) showing the changes from once every five minutes to twice an hour for various sizes of buildings.

Notations have been made on this chart showing the different classes of buildings, and the approximate air change may be ascertained by the location of their names on the chart.

From this the amount of air required for any given building of any cubic contents may be determined with comparative accuracy.

Size and Type of Fan.—The next important item is to determine the size and type of fan necessary to produce the desired air movement. There are a great many variables which are to be considered in this selection. It is a fact well known that the capacity of an encased fan varies directly with its speed, while the power varies as the cube of the speed. Thus it is seen that so far as possible it will be preferable to use a comparatively large fan and run it at a moderate speed, as a trifle added to the first cost will materially reduce the cost of running the fan. This is particularly true where the motive power is electricity, gas, or water; but does not amount to so much in the case of an engine-driven

fan, where the exhaust steam may be utilized in heating the air.

There are, however, other reasons why a large fan is preferable, particularly in public buildings and schools, as a lower speed may be maintained to move the same volume of air, thus reducing the vibration to a minimum. It is customary to use comparatively small fans, producing higher velocities in mill work, where the hum of other machinery makes the slight vibration of the fan entirely inaudible, and in other classes of buildings to use lower speeds, as great quiet becomes necessary.

A. R. Wolff, in his "Ventilation of Buildings," gives the following table as to fan capacities, but the speeds given are really the maximum which should be used even in factory work, and for school house, or public building work, they should be reduced from 25 to 50 per cent., the volumes delivered being proportionately less, while the power required will vary as the cube of the speeds, as stated above.

That is, should an 8-ft. fan be run but 100 R. P. M. instead of 200 R. P. M., the volume delivered will be 23,000 cu. ft., and the power will be but 3 H. P. when, by the table, a 5-ft. fan at 325 R. P. M., moves but 17,000 cu. ft. at an expenditure of 9.4 H. P. This very clearly demonstrates the economy of using a large fan.

Diam. Wheel in Ft.	Ordinary R. P. M.	Horsepower to Drive Blower	Capacity in Cu. Ft. per Min. at 1 Oz. Pressure
4	350	6	10,635
5	325	9.4	17,000
6	273	13.5	29,618
7	230	18.4	42,700
8	200	24	46,000
9	175	29	56,600
10	160	35.5	70,340
12	130	49.5	102,000
14	110	66	139,000
15	100	77	160,000

Should it be found preferable to use a different type from the ordinary encased fan, there are two alternatives: the disk or propeller fan, and the so-called cone fan.

The former may be relied upon under certain conditions, but when used in connection with a ventilating system, blowing air through pipes and over heating coils, it has been found very unsatisfactory, as it is not able to deliver air against any appreciable resistance, and it is so designed that the power to drive it increases with the resistance, no matter whether the fan is delivering air or not; while in the case of the other types of fans, the

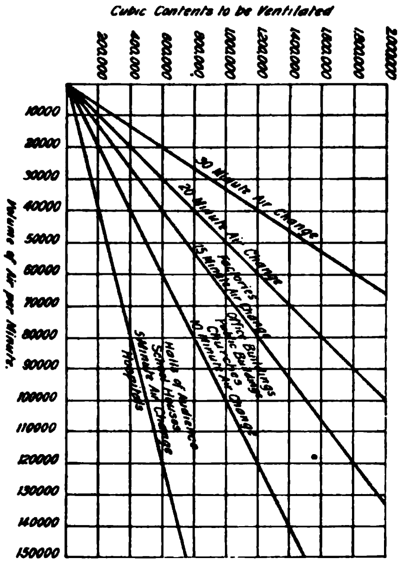


FIG. 1

greater the resistance the less the power required to propel the fan, the power consumption being at a minimum when all the outlets are entirely closed.

The cone fan is to be recommended in places where it is found inconvenient to install an encased fan. Many systems are designed on the basis of a central plenum chamber, from which the supply ducts lead to

the following example: Assume that the volume of air to be heated is 65,000 cu. ft. per min., or 3,900,000 cu. ft. per hour. The mean temperature of air is assumed at 60°, at which 13 cu. ft. weigh 1 lb. There will then be 300,000 lb. of air to be heated through 90° F., requiring 27,000,000 air units. The specific heat of air is .2377, and there will be required 6,417,900 B. T. U.

The Engineering Record, May 13, 1899, quotes from W. A. Blessed the statement that a heater used in connec-

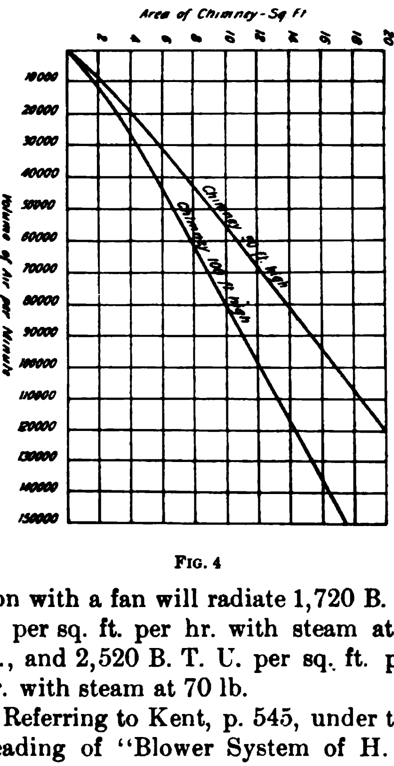


FIG. 4

tion with a fan will radiate 1,720 B. T. U. per sq. ft. per hr. with steam at 5 lb., and 2,520 B. T. U. per sq. ft. per hr. with steam at 70 lb.

Referring to Kent, p. 545, under the heading of "Blower System of H. & V.," is found the statement that with a fan used in connection with a heater, the transmission of heat is 8.5 B. T. U. per hr., per degree difference of temperature between air and steam. Taking the average between entering and leaving as the air temperature: If entering air is assumed at 0° F., and air leaving the heater is 90°, the average will be 45°.

The temperature of steam at 5 lb. gauge is 227° F., and at 80 lb. gauge is 324° F.; the temperature difference in the two cases being 182° and 279° respectively. This will allow each square foot of low-pressure heater 1,547 B. T. U. per hr., and each square foot of high-pressure heater 2,372 B. T. U. per hr. For convenience, let it be assumed that at 5 lb. each square foot gives up 1,500 B. T. U., and at 80°, 2,300 B. T. U. per hr. when used with a fan, the air passing over the coils at a comparatively high velocity. The number of feet of surface which will be required in either instance may be obtained by dividing 6,417,900 by either 1,500 or 2,300, which gives for the former 4,278 sq. ft. and for the latter = 2,790 sq. ft.

It will be observed that the total B. T. U. required are approximately 100 times the volume of air in cubic feet per minute and a short cut may be made by dividing the volume of air per minute by 15 for low-pressure steam, or by 23 for steam at 80 lb. From these factors a chart (see Fig. 2) has been plotted, showing the size of high- or low-pressure heater for any volume of air up to 150,000 cu. ft. per min.

In either instance the area through the heater should remain constant for the same volume of air, and the difference made up in the depth of heater; fewer rows being required where the steam pressure is higher.

The boiler power required depends directly on the amount of air to be heated, as does the size of heater, and may be obtained in a somewhat similar manner. It is a generally accepted standard that in a horizontal return tubular boiler 15 sq. ft. of heating surface constitutes a horsepower, and a

horsepower by the centennial standard means the evaporation of 30 lb. of water into steam at 70 lb. from 100°. From this it is seen that each square foot of heating surface must evaporate 2 lb. of steam per hour. To put it in round numbers, a pound of steam when it is condensed gives up approximately 1,000 B. T. U. Taking the same problem as previously presented of 65,000 cu. ft. per min., and 6,417,900 B. T. U. per hr., it is seen at a glance that in the vicinity of 6,418 lb. of steam must be evaporated, which will require a boiler of 214 H. P., having 3,209 sq. ft. of heating surface.

This on the basis of 1 sq. ft. of grate to 40 sq. ft. of heating surface will require 80 sq. ft. of grate. It will be observed that 214 is approximately $\frac{1}{300}$, and 80 is approximately $\frac{1}{800}$ of 65,000, and these factors have been used in Fig. 3, which shows the size of boiler and grate area necessary to warm the ventilating air.

The steam for driving the fan has not been taken account of, as it is assumed that this will be used in the heater at all times when any heating at all is required.

Size of Chimney.—It is very difficult to make up a simple formula for size of chimney relative to volume of air on account of the effective area being different for various areas of flue, and the efficiency of the chimney varying as the square root of the height.

Consequently, a chart has been plotted for chimneys 50 and 100 ft. high, basing figures on Kent's well-known formula H. P. $= 3.33\ (A - 0.6\sqrt{A}) \times \sqrt{H}$, in which $H =$ height of chimney in feet, and $A =$ gross area of flue, and using chimney sizes proportionate for relative boiler capacities, as shown in Fig. 3. (See Fig. 4.)

The height of chimney is, of course, liable to vary greatly, but it is intended that the chart shall show as nearly as possible the limits of size for a given volume of ventilating air.

Of course, where other factors for power are to be considered, it will simply be necessary to add to them the size of boiler and chimney for ventilating purposes to know the power and chimney area for the entire plant.

INSULATING POWER OF ELECTRICIANS' GLOVES

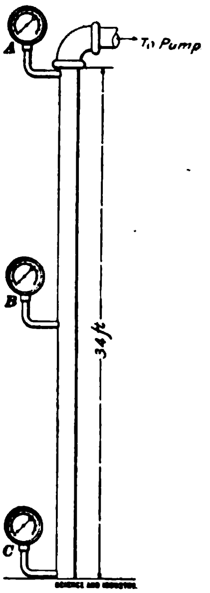
THE following item from the Electrical Review will be of interest to stationmen, linemen, or others who are in the habit of wearing rubber gloves when working around lines or electrical apparatus.

The Central Electric Laboratory, of Paris, has recently carried out a series of experiments bearing on the degree of insulation of electricians' gloves. The tests were made both with low pressure and high pressure. The practical conclusion arrived at is that insulating gloves cannot be considered to afford efficient protection against the dangers surrounding high-tension currents; it would even be preferable to proscribe their use altogether rather than rely upon their efficiency in the contact with dangerous connections. It is prudent only to consider them useful for working those parts already insulated from the lines, such, for instance, as non-metallic handles of switches. One glove, which withstood a potential difference of 12,200 volts, got pierced in one minute; another kind was pierced after three minutes with a potential difference of 1,000 volts only.

THE VACUUM IN THE SUCTION PIPE

BY WALTER W. EDWARDS

TAKE a pump located 34 feet above the surface of the water in the well and assume that it produces a perfect vacuum. While it is true that no pump is capable of producing a perfect vacuum, it may be assumed for the purposes of this discussion that the action of the pump is perfect and that a vacuum corresponding to 30 inches of mercury is formed. When the pump is started, water will rise in the pipe, owing to the pressure of the atmosphere on the surface of the water in the well. The pressure or weight of the atmosphere varies with the altitude, the humidity of the air, and general barometric conditions. Thirty-four feet is the height water will rise in a perfect vacuum at sea level with the barometer indicating 30 inches of mercury.



At 34 feet water will cease to rise because the weight of the water in the pipe per unit of area just counterbalances the weight of the atmosphere on a unit of area of the surface of the water in the well. Obviously, if the vacuum is perfect, the gauge at A will show 30 inches of vacuum.

At the gauge C, the effect of the vacuum produced by the pump at the upper end of the pipe, is just counterbalanced by the weight of the column of water in the pipe. As this column of water is 34 feet in height, and as it is produced by the perfect vacuum at the pump, it is plain that its pressure is just equal to the pressure of a 30-inch mercury column of equal area, and, therefore, the vacuum at C is $30 - 30 = 0$. That there is neither vacuum nor more than atmospheric pressure in the pipe at the gauge C is evident, because if there was more than atmospheric pressure in the pipe at this point, water would leave the pipe, while if there was a partial vacuum, more water would be taken into the pipe. As neither of these events take place, it is evident that the gauge at C will stand at zero. Similarly, a gauge at the middle point of the pipe, as B, would be acted upon by the perfect vacuum produced by the pump and the pressure of the column above the gauge. As the pressure of the column of water above the gauge is only half as great as the pressure of the column due to a perfect vacuum of 30 inches, we have the vacuum at B equal to the difference between the perfect vacuum of the pump and the mercury equivalent of the pressure of the half column of water above the gauge B, or $30 - 15 = 15$ inches of vacuum. Although there is a vacuum of 15 inches at B, more water will not enter the upper half of the pipe from the lower half, because the weight of the column of water below the gauge B just counterbalances, and is equivalent to, the vacuum at B.

In like manner, it can be shown that the vacuum at any point varies directly as the height above the water in the well, since the counterbalancing effect of the water above the chosen point varies directly as the distance from the point taken to the top of the water in the pipe.

CONDENSERS—I

CHAS. L. HUBBARD

THE expansion of steam in the cylinder of an engine causes its pressure to gradually fall until it finally reaches a point where it cannot be profitably used for driving the piston. At this stage some means must be provided for disposing of the vapor, in order to prevent back pressure during the return stroke of the piston. If the atmosphere did not exert a pressure of its own, the steam could be disposed of at once by exhausting into the open air. But there is in reality a pressure of nearly 15 pounds per square inch due to the weight of the atmosphere, from which it follows that the steam from a non-condensing engine cannot be expanded below this pressure to any advantage, as it must eventually be exhausted against atmospheric pressure on the return stroke.

If by any means this back pressure can be removed, it is evident that the engine will not only be aided by relieving the resistance upon the exhaust side of the piston, but the steam can be expanded in the cylinder quite, or nearly, to absolute zero pressure, and thus its full expansive power can be obtained.

If the steam is discharged into a closed chamber in such a manner that it comes in contact with a spray of cold water or with a series of tubes through which cold water is circulated, it will be deprived of nearly all of its latent heat and will condense. In either case the act of condensation is practically instantaneous. As the water of condensation has only about $\frac{1}{1800}$th of its original volume, it follows that the remainder of the space is void and that no pressure exists. If the expanded steam from an engine is conducted into this empty space, it will meet with no resistance and the limit of its usefulness will be reached. An arrangement of this kind in practical form is called a condenser. The cold water that produces the condensation is the injection water, and the heated water on leaving the condenser is called the discharge water.

In order that the action of the condenser may be continuous, the flow of the injection water and the removal of the discharge water (together with the condensation) must also be continuous. In practice it is not possible to obtain a perfect vacuum for several reasons:

First, because the injection water (in the case of a spray) and the condensed steam (where the cold water is circulated in pipes) are heated to a certain extent and emit a vapor having a pressure corresponding to their temperature.

Second, because of the pressure of the air which enters in small quantities with the injection water and steam, and which also leaks in through faulty connections and badly packed stuffing-boxes.

The state of vacuum in a condenser is usually expressed in inches of mercury. For example, if the chamber of a condenser be connected by a rubber tube with the space above the mercury in a barometer, and the mercury column should fall to 26 inches, the condenser would be said to have 26 inches of vacuum. If the barometer stood at 30 inches before the rubber tube was attached, that is, when the space above the mercury was a vacuum, it would indicate that there was a pressure in the condenser equal to $30 - 26 = 4$ inches of mercury, or $4 \times .49 = 1.96$ pounds per square inch, which corresponds to a temperature of about 126°,

and if the condenser were absolutely air-tight, would indicate that the water within was at that temperature. In order that the air may not accumulate in the condenser and destroy the vacuum, it is withdrawn, together with the heated water, by means of a pump.

The value of a condensing apparatus to any engine depends largely on the temperature of the injection water, the steam pressure and cut-off of the engine, and also on the engine itself. The quantity of water required to completely condense the steam from an engine depends on two conditions: the total heat and weight of steam and the temperature of the injection water. With 26 inches of vacuum and injection water not above 70°, the required amount of injection water will be ap-

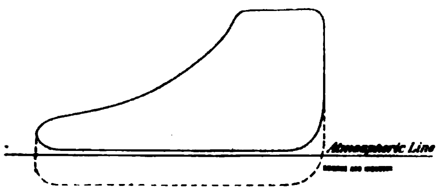


FIG. 1

proximately from twenty to thirty times that fed into the boilers. If the temperature of the injection water is lower, a less quantity is required, and if higher, the amount must be increased; for example, at 80°, thirty-five times, and at 90°, fifty-two times the amount of feedwater is required. The exact amount in each special case can be computed, theoretically, by the following formula:

$$Q = \frac{S-(D-32)}{D-I};$$

in which

$Q =$ weight of injection water per pound of feedwater;

$S =$ total heat of steam above 32° at exhaust pressure;

$I =$ temperature of injection water;

$D =$ temperature of discharge water.

For convenience, we will give that portion of a steam table covering the usual range of terminal pressures:

Terminal Pressure, Absolute	Total Heat Above 32° in B. T. U.	Terminal Pressure, Absolute	Total Heat Above 32° in B. T. U.
5	1,131.4	20	1,151.5
6	1,133.8	21	1,152.2
7	1,135.9	22	1,153.0
8	1,137.7	23	1,153.7
9	1,139.4	24	1,154.5
10	1,140.9	25	1,155.1
11	1,142.3	26	1,155.8
12	1,143.5	27	1,156.4
13	1,144.7	28	1,157.1
14	1,145.9	29	1,157.7
15	1,146.9	30	1,158.3
16	1,147.9	35	1,161.0
17	1,148.9	40	1,163.4
18	1,149.8	45	1,165.2
19	1,150.6	50	1,167.6

The use of the formula will be made clear by applying it to a practical example.

A 100 H. P. engine, requiring 20 pounds of steam per H. P., has a terminal pressure of 10 pounds absolute. The temperature of the injection water is 70° and we will assume a temperature of 120° for the discharge water, which corresponds approximately to 26 inches of vacuum. What will be the weight of injection water required?

From the above conditions we have

$$S = 1,140.9$$
$$I = 70$$
$$D = 120$$

Substituting in the formula, we have

$$Q = \frac{1,140.9-(120-32)}{120-70} = 21+.$$

The weight of steam required to supply the engine is $100 \times 20 = 2,000$ pounds per hour. Therefore, the weight of injection water is

$$2,000 \times 21 = 42,000 \text{ pounds}.$$

The reason for the above formula is evident. One pound of steam at 10 pounds pressure contains 1,140.9 B. T. U. above a temperature of 32°. That is, if the steam were condensed and cooled to 32°, 1,140.9 B. T. U. would

be given off. But in the example it is only cooled to 120°. One B. T. U. will raise the temperature of 1 pound of water 1°, or, in other words, 1 B. T. U. will remain in the condensed steam for each degree that its final temperature is above 32°.

Therefore, the heat given out by condensing 1 pound of steam at 10 pounds pressure and cooling it to 120° is $1,140.9 - (120 - 32) = 1,052.9$ B. T. U.. The heat absorbed by 1 pound of water in raising it from a temperature of 70° to 120° is $120 - 70 = 50$ B. T. U.

Therefore, $1,052.9 \div 50 = 21+$, the pounds of water which will be required to absorb the heat given off by the condensation and cooling of 1 pound of steam under the conditions stated in the example. The matter of subtracting 32 from the temperature D affects the result but little and is often omitted in practice, and the formula is written $Q = \frac{S - D}{D - I}$, but for purposes of demonstration it is necessary to include it.

The advantages gained by using a condenser are an increase in the horsepower of an engine and also a greater economy in the use of fuel per horsepower developed. The power exerted by a steam engine during a single stroke of the piston is due directly to the difference between the pressures acting on the opposite sides of the piston. A vacuum does not in itself give power, but it removes the resistance from the exhaust side of the piston, and therefore adds just so much to the steam side. The value of a vacuum of 26 inches of mercury to an engine, making due allowance for the cost of production, may be approximated by considering it equivalent to a net gain of 12 pounds average pressure per square inch of piston area. This is shown graphically in Fig. 1, in which the full line represents the indicator card when exhausting into the atmosphere. If the exhaust be connected with a condenser and the points of cut-off and release remain the same, the back-pressure line will drop to the position shown by the dotted line, and the difference between the two back pressure lines will be added directly to the mean effective pressure, because it is a constant effective pressure extending throughout the entire stroke. From this it is evident that the amount of power gained bears practically the same ratio to the power developed by the engine when non-condensing, as 12 pounds does to the mean effective pressure when running under the same conditions. So if the mean effective pressure is known in any case, a close idea may be had of the percentage of gain in power that will be derived by the use of a vacuum with a non-condensing engine.

The formula for determining the indicated horsepower of an engine is

$$\frac{P \times L \times A \times N}{33,000},$$

in which

$P =$ mean effective pressure in pounds per square inch acting on the piston (M. E. P.);
$L =$ length of the stroke in feet.
$A =$ area of piston in square inches;
$N =$ number of single strokes per minute.

By substituting 12 for P in this formula, it will give the H. P. gained by a vacuum of 26 inches when applied to a non-condensing engine.

The gain in fuel by the use of a condenser, when the power remains the same, is illustrated in Fig. 2. The two diagrams were taken from the same engine. The first, shown by the dotted line, was obtained when running non-condensing, and the second by running condensing. The areas of the two cards

are equal, so the work done per stroke is the same in each case.

The cut-off, however, occurs at $\frac{1}{3}$ stroke in the first, and at $\frac{1}{5}$ in the second, so that the difference between $\frac{1}{3}$ and $\frac{1}{5}$ of a cylinder of steam is saved at each stroke.

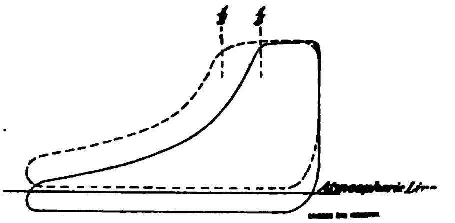


FIG. 2

The percentage of saving is obtained as follows: Assuming the sectional area of the cylinder to be 1 square foot, the volume of steam used per stroke in the first case will be $1 \times .33 = .33$ cubic feet, and in the second $1 \times .2 = .2$ cubic feet. The saving will be $.33 - .2 = .13$ cubic feet per stroke, or $.13 \div .33 = 40$ per cent., nearly.

The approximate M. E. P. for any given case may be found by use of the following ratios:

Cut-off	Ratio of M. E. P. to Initial Pressure (Absolute)
$\frac{1}{12}$	.29
$\frac{1}{10}$	.33
$\frac{1}{8}$	.38
$\frac{1}{6}$	.46
$\frac{1}{5}$	.52
$\frac{1}{4}$	.60
$\frac{1}{3}$	.70
$\frac{1}{2}$	.85
$\frac{5}{8}$	.92

The ratios given are for absolute pressures. The use of the table as applied to actual conditions can best be shown by a few practical examples.

A non-condensing engine cuts off at $\frac{1}{3}$ stroke; the initial pressure is 85 pounds gauge, what is the M. E. P.? 85 pounds gauge $= 85 + 15 = 100$ pounds absolute.

The ratio for $\frac{1}{3}$ cut-off is .70; therefore, the M. E. P. is $100 \times .70 = 70$ pounds; but this is on the supposition that the engine exhausts into a perfect vacuum. Under ordinary conditions the pressure in the exhaust pipe of an engine open to the atmosphere will be about 2 pounds gauge, or 17 pounds absolute, so that in the above example we must subtract 17 from the result found, which will give us $70 - 17 = 53$.

Briefly, we may write

$$[(P + 15) \times \text{ratio}] - 17 = \text{M. E. P.}$$

for a non-condensing engine, and

$$[(P + 15) \times \text{ratio}] - 3 = \text{M. E. P.}$$

for a condensing engine, in which P = boiler pressure (gauge).

Three pounds back pressure in the condenser, corresponding approximately to 26 inches of vacuum under the conditions already stated, is good average practice in first-class plants.

An 18″ × 36″ non-condensing engine runs at a speed of 200 revolutions per minute and cuts off at $\frac{1}{4}$ stroke; boiler pressure 95 pounds gauge. What gain in H. P. can be obtained by running condensing with a vacuum of 26 inches of mercury, and what will be the final H. P.?

M. E. P. $= [(95 + 15) \times .60] - 17 = 49$, and the I. H. P. would be from the formula already given

$$\frac{49 \times 3 \times 254 \times 400}{33{,}000} = 452.$$

The I. H. P. when running condensing would be found in the same way by taking a back pressure of 3 pounds instead of 17, and we have

$$\text{I. H. P.} = \frac{63 \times 3 \times 254 \times 400}{33{,}000} \doteq 582$$

as the final H. P. with a gain of $582 - 452 = 130$ H. P.

Taking the same engine, what percentage of saving could be made by shortening the cut-off and keeping the power the same?

The first step is to find the new point of cut-off which will be required to maintain the same power of the engine. This may be obtained algebraically by the formula already given for the M. E. P.

In this case the initial and mean effective pressures remain the same, the only change being in the back pressure, so that we may write

$$[(95 + 15) \times R] - 3 = 49,$$

and solve for R, which gives us

$$(110\,R) - 3 = 49,$$

or $$R = \frac{49 + 3}{110} = .47.$$

Looking in the table of ratios we find that .46 corresponds to a cut-off of $\frac{1}{6}$, which we may take in this case.

The saving in steam per stroke will then be $\frac{1}{4} - \frac{1}{6} \div \frac{1}{4} = \frac{.25 - .166}{.25} = 33$ per cent. saving of steam.

This may be carried still further by assuming the water rate of the engine when running non-condensing to be 30 pounds per H. P. per hour, and the efficiency of the boiler to be such that 9 pounds of water are evaporated per pound of coal. In this case the weight of steam required will be $452 \times 30 = 13,560$ pounds per hour, and the weight of coal will be $13,560 \div 9 = 1,506$ pounds per hour. We have already found the saving in steam to be 33 per cent., and as the saving of coal is in direct proportion, we shall have a saving of $1,506 \times .33 = 497$ pounds of coal per hour.

These figures are somewhat higher than would be obtained in practice, owing to leaks, condensation, and other losses, but the methods of computation are the same.

Whether it will pay in any particular case to install a condenser will depend on various conditions, among which are size and water rate of engine, cost of injecting water, and whether the exhaust steam can be used for heating purposes or not.

NOTES ON PACKING

PACKING is one of the numerous commodities with which every engineer has to do. Packing in one sense is like a man's talents, when properly applied profitable results may be realized, but when misapplied the result is unceasing annoyance and frequently leads to expensive trouble. It is not a difficult matter nowadays to find a packing applicable to every condition to be met with in regular engineering practice.

It must be remembered in this connection that all engineers are not permitted to select their packing, and it is frequently due to the narrow mindedness of the proprietor that his packing costs him as much as it does. Of course when an engineer has not kept an account of his supplies and is unable to judge by former experiences which kind would best suit his present needs, it is six of one and half a dozen of the other whether the proprietor selects the packing or whether it is left to the engineer. There are scarcely two kinds of packing that will give exactly the same results under the same conditions and when treated in the same manner. It is evident, therefore, that different treatment must be given nearly every kind and brand of packing made.

More or less experimenting may have to be done before the proper treatment can be determined, and even

though these experiments may result in a small loss of packing, it will be cheaper in the long run, namely, when

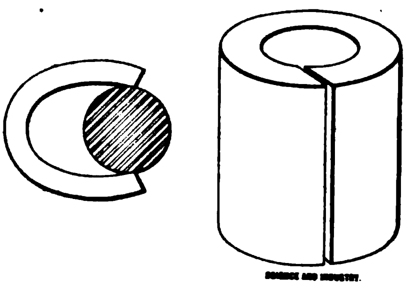


FIG. 1

the proper treatment has been decided upon.

It is a part of the business and duty of the engineer to make such experiments as he can and to determine the most economical methods to be adopted in his particular plant. These same methods may not prove successful in another plant, but this should make no difference, because the treatment accorded the packing is largely dependent upon local conditions and circumstances. There is scarcely any kind or brand of packing, not excepting metallic packing, that is not benefited by the use of graphite, which is frequently called plumbago or black lead. Strictly speaking, the benefit to be derived from the graphite is not due so much to any improvement in the

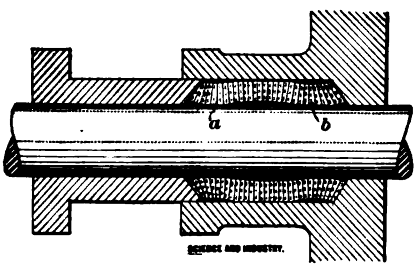


FIG. 2

packing itself as it is in the wearing surfaces, which come in contact with it. The effect in either case is practically the same.

First let us consider the application of what is frequently styled "solid" packing, that is, packing which is made in one piece, as in Fig. 1, which also illustrates the manner in which it is put on the rod. These rings are made of the proper length and thickness so as to just fit the rod and stuffingbox, when the latter is cold. This is what the makers recommend and desire, at least, but this packing will not always be found to do so in practice, and it is the result of failure in this direction that we are to briefly consider. The failure referred to is not always traceable to any mistakes or neglect on the part of the engineer, nor to the original quality of the packing, but it is frequently due to

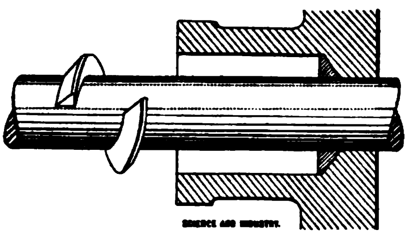


FIG. 3

unavoidable causes, such as unequal wear on the rod or in the cylinder, or to the packing having been previously wet and dried. It frequently happens that one piece of packing will absorb more oil than others; this will make a considerable difference in its working steam-tight, particularly if steam of high pressure is used.

When the packing does not fill the stuffingbox the result will be similar to that shown in Fig. 2. This, of course, represents an exaggerated illustration of the real effect upon the packing, but serves to illustrate the tendency of the gland to crowd the packing away from the rod instead of against it. If the packing does not completely fill the stuffingbox before the gland is placed in position to be

screwed up, it will be seen that no amount of tightening will help matters in the least; that is for more than a very few minutes. When the gland is

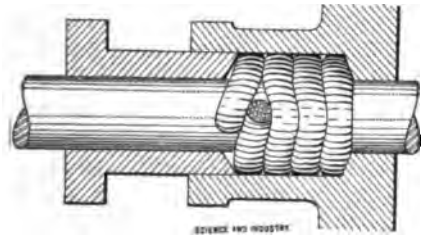


FIG. 4

tightened the pressure at the points *a* and *b* is materially increased, and the surface under pressure is so small that the packing heats rapidly and soon burns away at these points. When packing of this kind does not fit the stuffingbox and the rod snugly before putting the gland in place, it is much better not to attempt to use it at all, but return it to the makers or the agent and get a piece of the proper size. When the packing fits as shown in Fig. 2, a tight joint cannot be had under any circumstances nor for any length of time; it will leak when the gland is slackened and when it is screwed up with the fingers or with a wrench. When packing of this kind is employed, the gland and the bottom of the stuffingbox should be square instead of "dished," as shown in Fig. 2.

In order to obtain a "square" gland, it is not always advisable to bore out the stuffingbox nor face off the gland, for it would be cheaper to make a change in the kind of packing. If the conditions are favorable to the use of the "solid" packing, which includes a true running crosshead and rod, a smooth rod of uniform diameter and a stuffingbox of sufficient depth, the bottom of the stuffingbox and the gland may be made square without changing the form of the box or gland. This may be done by making a ring of soft copper, the cross-section of which will be wedge shape, as shown in Fig. 3, and the taper will be the same as the bevel on the gland. The ring is to be split and placed on the rod in the manner shown and then bent back to the form of a ring and slid into its proper place; one against the bottom of the stuffingbox and the other against the gland. If the engine has a piston rod of two inches diameter or more, it will be better to allow a little clearance between the bore of the rings and the rod. When soft packing is again used, all that is required to adapt the gland and the stuffingbox to it is the removal of the copper rings, which may be accomplished in less than five minutes. When using ring or spiral packing, particularly of the square or wedge-shape variety, the sections should fit the stuffingbox snugly when first put in, because the maintenance of a tight joint at this point is not dependent so much upon the pressure exerted by the gland or steam pressure as it is upon the expansion of the packing by the heat and the absorption of moisture. This kind of packing gives good results with a square gland and stuff-

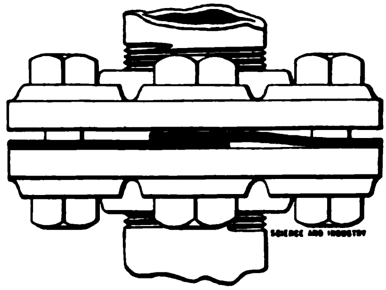


FIG. 5

ingbox as previously described. The manner of cutting packing has a great deal to do with the results obtained, more so perhaps than would at first seem probable.

When the packing is cut into rings and inserted one ring at a time, care should be taken not to cut it too long or too short. If cut too short the ends

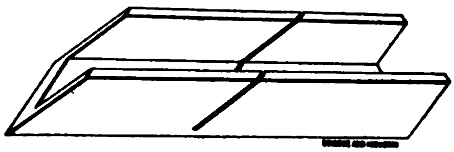


FIG. 6

of the rings will not come together, and considerable pressure must be brought to bear on the packing in order to effect a steam-tight joint between the several rings. The space left between the ends of the rings will gradually become wider as the packing becomes older and harder, due to the shrinkage which invariably takes place in time. This in turn calls for additional pressure on the packing, which not only destroys its expansive qualities, but tends to injure the rod by the hard and unyeilding surface thus produced. When the rings are cut too long the pressure brought to bear by screwing up the gland, even with the fingers, is not evenly distributed, and therefore one of two evils will result: first, the packing will either leak steam, or second, the pressure necessary to prevent leakage will injure the packing where it is squeezed too tightly. This may be understood by referring to Fig. 4, which represents a ring cut too long, showing how the pressure will be unevenly distributed and that it will be too great in line with the uneven joint. Now an engineer knows that he cannot make a successful flange joint by allowing the ends of the gasket to overlap, as shown in Fig. 5. The packing at the lap will be squeezed too tightly while the remainder of the gasket will not receive pressure enough. The same principle holds true concerning the packing in the stuffing-box. A good quality of soft packing properly applied requires a very slight pressure to render it steam-tight.

A good way to cut packing is shown by Fig. 6. This resembles a miter box and consists of a small trough of hard wood. A slot is cut through the sides, the use of which will be presently explained. The end of the trough is cut off at about the same angle as the slots. Any sharp knife having a sufficient length of blade will be found serviceable for this work. The length of the trough measured from the slots to the beveled end is made equal to the required length of the packing rings. If several lengths are to be cut with the same trough, several slots may be provided, one for each length of ring. In this case the size of the rod corresponding to a given slot should be marked on the outside of the trough.

When a ring of packing is cut off square and bent around a rod, the ends will usually be found to be in the position shown in Fig. 7. The ring on the whole is too short, and the result obtained in a stuffingbox will be similar to that which would be obtained by the ring shown in Fig. 8. The inside of the ring, Fig. 7, is of about the right length but the outer edge is too short. Now, in order to have the ends of the ring fit together nicely, they should be cut at an angle, and in order to make a

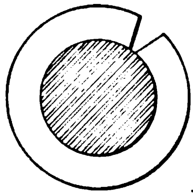


FIG. 7

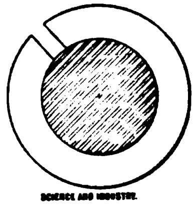


FIG. 8

good joint, the ends should be beveled as shown in Fig. 9.

Nearly all packing will expand more or less when it becomes heated and will lengthen when it is compressed by the

gland, so that some allowance must be made for this expansion and elongation. The rings when new should, therefore, be cut a trifle short, as indicated in Fig. 9,

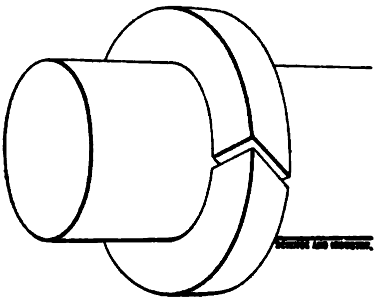


Fig. 9

and the size of the packing should be such that it may be inserted with the fingers and still fit snugly. The following table shows what has been found in practice to be a satisfactory length of rings for different diameters of piston and other rods, and for various sizes of packing. The length of the rings given in the table correspond to the distance between the toe of one of the beveled ends of the packing to the heel of the other.

When packing is to be cut without the assistance of the trough, or gauge, as it might be called, the difference in the lengths of the two sides of the packing when bent around the rod will not be taken into consideration, but when constructing a gauge it is well to do so, for no more thought need be given the matter of length or of the proper angle after the gauge is once constructed. Where an engineer has perhaps two or more engines, a condenser and a number of pumps to care for, there will usually be quite a variety of rods of different diameters to cut packing for, and it is under these circumstances that the gauge will be found particularly useful.

One cause of injury to packing lies in the vertical movement of the rod due to the crosshead or piston being either too high or too low. It is impossible to keep a stuffingbox tight for any length of time when the rod does not run perfectly true. The effect upon the packing is shown in Fig. 10, when the crosshead is at one end of its travel. The rod will squeeze the packing too tightly on one side and relieve the opposite side to such an extent as to permit steam to blow through. This condition will be particularly noticeable as the packing grows older and harder, losing its elasticity and ability to adjust itself to the constantly increasing and decreasing space between the rod and the stuffingbox. Another cause of much dissatisfaction among engineers, with packing, lies in the fact that the stuffingboxes on the majority of engines and on fully 95 per cent. of the pumps made in this country are too shallow. Of course this is a matter that is beyond the control of the engineers, and it is not our purpose to tell engineers, what they can't do, but what they can do. It would be impossible for the busy engineer to make the stuffingboxes deeper, therefore, to tell him that they should be deepened would do him about as much good as to inform him that in order to be a millionaire he must have a million dollars.

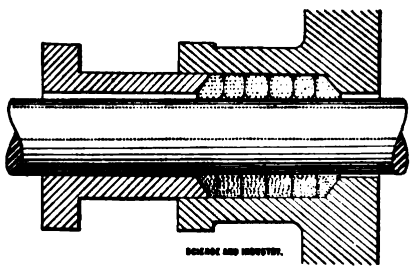


Fig. 10

The stuffingboxes on the pumps (and some makes of engines), particularly of the smaller sizes, are about in proportion to those on larger machines.

Now a stuffingbox that is 1¼ times its diameter in depth will do very well for rods of 2½ inches diameter and upwards, but it is not deep enough for a rod of 1 or 1¼ inches in diameter. The space surrounding the rod for the packing is usually larger in proportion to the diameter of the rod in a pump than it is

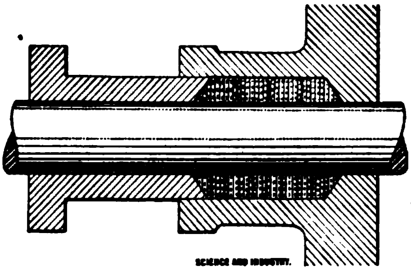


Fig. 11

in an engine having a fair sized rod, say, of the diameter mentioned. An engineer usually employes as large a ring as possible in order to insure a snug fit, and the result is that he can get fewer rings into the pump stuffingbox than he can into the one in the engine. It ought to be just the reverse, for it is more difficult to properly pack rods of 1½ inches diameter and under than it is the larger sizes. A stuffingbox should be made of such a depth that when using the proper size of ring the same number of rings of packing can be placed in all sizes of boxes.

In Fig. 11 is a stuffingbox showing the ends of a few large packing rings on one side and a larger number of smaller rings (narrower) on the other. Whatever the theory is concerning packing, it will make but little difference with the practical results, which have proved that to a very great extent the pressure required, the tightness of a stuffingbox and the durability of a given kind of packing depends more upon the number of rings than upon the size. When a stuffingbox is found to be too shallow, try putting in a larger number of narrow rings, which of course should fit the box snugly.

TABLE SHOWING LENGTH OF PACKING RINGS

Diam. of Rod	Thickness of Packing or Distance Between Piston Rod and Stuffingbox																
	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4	1 3/8	1 1/2
3/4	3 1/2	3 11/16	3 13/16														
7/8	3 7/8	4	4 1/4	4 7/16													
1	4 5/16	4 3/8	4 5/8	4 13/16													
1/8	4 11/16	4 13/16	5	5 3/16													
1/4	5	5 3/16	5 3/8	5 1/2													
3/8	5 7/16	5 9/16	5 13/16	5 15/16	6 1/8												
1/2	5 13/16	5 7/8	6 3/16	6 3/8	6 9/16												
5/8	6 3/16	6 5/16	6 1/2	6 11/16	6 7/8												
3/4	6 1/2	6 3/4	6 7/8	7 3/16	7 5/16												
7/8	6 7/8	7 1/8	7 5/16	7 1/2	7 11/16												
2	7 5/16	7 7/16	7 11/16	7 3/4	8 1/16	8 5/16											
1/8		7 7/8	8 1/16	8 3/8	8 9/16	8 11/16											
1/4		8 5/16	8 7/16	8 13/16	8 13/16	9	9 5/16										
3/8		8 11/16	8 13/16	9 1/16	9 5/16	9 1/2	9 11/16										
1/2			9 3/16	9 1/2	9 11/16	9 13/16	10	10 1/4	10 7/16								
5/8			9 5/8	9 13/16	10	10 3/16	10 3/8	10 9/16	10 3/4								
3/4				10 3/16	10 3/8	10 9/16	10 3/4	11	11 3/16								
7/8				10 9/16	10 3/4	11	11 3/16	11 3/8	11 9/16								
3				11	11 5/16	11 3/8	11 9/16	11 3/4	12								
1/4					12	12 1/4	12 3/4	12 9/16	12 3/4	13	13 1/8						
1/2					12 3/4	13	13 1/4	13 5/16	13 1/2	13 3/4	14						
3/4					13 1/2	13 3/4	14	14 1/8	14 5/16	14 1/2	14 13/16						
4					14 5/16	14 1/2	14 13/16	15	15 3/16	15 1/4	15 1/2	15 11/16	15 7/8				
1/4					15	15 1/4	15 5/8	15 5/8	16	16 1/8	16 1/4	16 7/16	16 5/8				
1/2					15 13/16	16	16 3/16	16 3/8	16 5/8	16 13/16	17	17 3/16	17 3/8				
3/4							17	17 3/16	17 3/8	17 9/16	17 13/16	18	18 3/16				
5							17 13/16	18	18 3/16	18 3/8	18 9/16	18 3/4	18 15/16	19 5/8	19 7/8		
1/4							18 9/16	18 13/16	19 1/16	19 5/16	19 5/16	19 5/8	19 3/4	20 1/8	20 9/16		
1/2									19 13/16	20	20 1/8	20 1/4	20 1/2	21	21 3/16	21 7/8	21 15/16
3/4									20 9/16	20 7/8	21	21 1/16	21 5/16	21 3/4	21 15/16	22 3/8	22 5/8
6									21 5/16	21 7/16	21 5/8	21 13/16	22 1/8	22 7/16	22 5/8	22 7/8	23 3/8

WIRELESS TELEGRAPH SIGNALS ACROSS THE ATLANTIC

W S HENRY

OUR readers have doubtless seen the fact stated in the daily papers that Marconi has signaled across the Atlantic Ocean. Since this is true, it may interest them to know a little more about this surprising and successful experiment.

A station at Poldhu, Cornwall, England, and a station in Ireland, about 220 miles away, have been regularly communicating with one another for some time by means of Marconi's wireless telegraph system.

Without any blowing of trumpets beforehand, Marconi quietly prepared to test his system across the Atlantic. At Poldhu he installed a very powerful transmitter of electrical waves, probably an extra powerful induction coil. At St. Johns, Newfoundland, about 2,100 land miles from Poldhu, he set up his receiving apparatus. As far as we know now this consisted of a delicate coherer and other essential apparatus, including, however, a telephone receiver, probably in place of the relay used for shorter distances. The receiver was used because it is so much more sensitive to feeble electric currents than a relay. In place of a tall mast he used kites that elevated his vertical receiving wire probably 200 feet above the top of Signal Hill, at St. Johns. Signal Hill itself is a cliff 300 feet above the sea. Before leaving England he had arranged to have the letter S signaled to him repeatedly, at short intervals, for three hours each day between 3 and 6 A. M., Greenwich time, after he should send word to them by a submarine cablegram that he was ready. In a letter to the New York Herald, Marconi gives the following account of the test:

"I received on Thursday, Dec. 12, indications of the signals at 12:30 P. M. (Newfoundland time), and with certainty and unmistakable clearness; at 10 minutes after 1 quite a succession of "S's" were received with distinctness. A further number were received at 20 minutes after 2, the latter not so good. Signals were received Friday, but not so distinct as on Thursday.

"I am of the opinion that the reason why I did not obtain continuous results were: First, the fluctuations in the height of the kite, and second, the extreme delicacy of my receiving instruments, which were very sensitive and had to be adjusted repeatedly during the course of my experiments."

For increasing the distance of sending wireless telegraph signals from 220 to 2,100 miles at one bound, so to speak, Marconi is certainly deserving of all the fame he has received. It is reported that he refused an offer of $3,000 for three lectures to be given in the United States. He said that he was too much interested in his work to accept any such offer. Furthermore, the breaking of his engagement with an American girl is due partially to the same cause.

Though satisfied of the genuineness of the signals, and that he has succeeded in his attempts to establish communication across the Atlantic without the use of wires, Marconi wishes it understood that the system is yet only in an embryonic stage. The possibility of its ultimate development is, however, demonstrated by the success of the present experiments with incomplete and imperfect apparatus, although the signals could only be received by the most sensitively adjusted apparatus, working under great difficulties, owing to the conditions prevailing at St. Johns.

Besides the proper arrangement of

suitable apparatus, the transmitter must be very powerful, and hence requires the expenditure of abundant electrical energy. It was due to the lack of such a transmitter for use at St. Johns that no attempt was made to send signals from there to Cornwall. The signal for the letter S, which was used in these experiments, consists of three electrical impulses of equal length and equally spaced. The letter V is said to be usually employed in the Marconi system for test signaling, but it was avoided in this case, as a signal might otherwise have been received from a station other than that at Poldhu. This experiment between St. Johns and Poldhu proves that the curvature of the earth does not injuriously affect the transmission of signals. The electromagnetic waves sent out by the transmitter seem to slide over the surface of the earth, instead of following the straight line from the transmitting to the receiving station through the earth. A straight line through the earth from St. Johns to Poldhu would show that the summit of the ocean was about 142 miles above this line midway between the two places. Either the electromagnetic waves or disturbances must slide over the surface, or through the air, or else the earth must be transparent to them. Otherwise, if the transmitter and receiver had to be on a straight line which cleared the surface of the ocean, the transmitter or receiver would have to be elevated about 650 miles. Even supposing the water to be perfectly transparent to the electromagnetic waves, the bed of the ocean midway between the two stations is over 139 miles above the straight line joining them. It is difficult to understand why a wire elevated only 500 feet above the surface of the ocean at St. Johns is able to intercept the waves originating at Poldhu. The best explanation seems to be that the electrical waves slide or bound in immense steps (probably 2,000 feet high) over the surface of the ocean. We know that it is very much more difficult to transmit these waves the same distance over the irregular surface of the land. The surface of the ocean acts as a good reflecting surface, and the long vertical waves seem to bound along like a marble that is thrown at an angle upon a smooth stone sidewalk.

THE HORSEPOWER OF ENGINES AND BOILERS

W. H. WAKEMAN

A COMPARISON OF THE STANDARDS ADOPTED FOR CALCULATING POWER DEVELOPED

MUCH has been said and written during the past year concerning the proper way to determine the power of an engine, also of a boiler, and while the former is usually treated in a plain and comprehensive way, the result of which is beneficial to those who are seeking after knowledge (which includes every progressive engineer and other mechanic), the latter is often presented in a manner that results in confusion and dissatisfaction, although it may not be so intended by those who give us their ideas on the subject.

This unsatisfactory state of affairs is largely due to the fact that some writers and teachers fail to comprehend the fact that the standard adopted for the horsepower of an engine, has no connection whatever with the rule for calculating the horsepower of a boiler, as the two are entirely different, and consequently should be kept separate. An idea is sometimes advanced to the

effect that there is no such thing as the horsepower of a boiler, but this calls for only a passing notice, for when the horsepower of pumps, chimneys, shafting, belts, and ropes is calculated, the power of a boiler certainly can be determined with precision.

The principle argument advanced by those who claim that the boiler is not in the comprehensive list, is that we cannot tell how much power it will develop until it is set and fired up, also that we must know the power developed by the engine which it supplies with steam, before we can tell what the boiler is doing. The foregoing consists of two distinct propositions and will be treated so here.

I have never met an engineer who claimed that the power of an engine could not be determined in advance, yet there is as much difference in the results obtained from engines of the same size, as from boilers containing the same amount of heating surface.

For five years I had charge of a fine Corliss engine that was rated at 75 horsepower. Its cylinder was 16 × 36 inches. At the present time there is a new plant in course of construction in this vicinity that requires a 150-horsepower engine. On inquiring the size of cylinder, I was informed that it is 16 × 32 inches.

Comparisons of other engines might be made which show a greater discrepancy than this, by referring to engine-builders' catalogues, but the sample taken from the list of those with which I am familiar will answer every purpose here. The point that I wish to make clear is, that because engines of the same size (or nearly the same) are made to develop much more power in some places than in others, it does not destroy or make void the standard set for determining the power of an engine, and the same reasoning applies to the boiler.

Some writers admit the standard for boiler horsepower, but afterwards claim that the difference between the engine and the boiler power makes the latter of no value. This helps about one thing, namely, to further confuse and mystify those who do not thoroughly understand the subject. The object of this article is to demonstrate that it is a very simple matter to tell the power developed by a boiler, under any conditions found in ordinary practice, regardless of the purpose for which the steam is used.

This can be determined in advance by noting the performance of similar boilers in other places, just as accurately as the power of an engine can be foretold.

We are solemnly told that this is not possible because we do not know how strong the draft will be, nor the quality of coal to be used, nor yet the skill with which it will be fired.

All this is admitted, but we never can tell what the initial pressure on the piston of an engine will be in advance, nor yet the skill with which the valves will be set, and all of these factors make a difference in the power developed. It is unreasonable to admit it in one case and deny it in the other.

The well-known standard for calculating the power developed by a boiler is to allow 1 horsepower for each 30 pounds of water evaporated into dry steam per hour, when the feedwater enters at 100° F. and the pressure carried is 70 pounds. This means that if you are carrying 70 pounds pressure, and by looking at your water meter and making a simple calculation you find that 3,000 pounds of water are evaporated, you are developing 100 horsepower in that boiler, if the feedwater is at 100°.

What the steam is used for does not make the slightest difference, for it may be utilized to run engines and pumps, heat a building or make beer, and the result will be 100 horsepower just the same.

Another stumbling block seems to be found in the fact that many boilers are not run under the conditions above mentioned, but that only makes it necessary to use a few more figures in the calculation.

The formula by which any problem of this kind may be solved is as follows: $\frac{1,110 \times 30}{H} = P$, in which $H =$ the total heat of steam at observed pressure minus the temperature of the feed water, and $P =$ pounds of water that must be evaporated to constitute one horsepower under given conditions.

Applying this to the boilers I have charge of at present results as follows:

The pressure carried is 60 pounds by the gauge, or 75 pounds absolute, the total heat of which is 1,207.

During a test the average temperature of feedwater was 214°, therefore the value of H is $1,207 - 214 = 993$.

Substituting for the letters their values results as follows:

$$\frac{1,110 \times 30}{993} = 33.5 \text{ pounds.}$$

33.5 becomes the constant for these conditions, so that if the water meter indicates that 5,360 pounds of water have been evaporated in an hour, then it requires but little time to show that these boilers have developed $5,360 \div 33.5 = 160$ horsepower.

The steam contains $\frac{1}{2}$ of 1% moisture, which is too small for consideration, and the water meter was proved by calibration to be practically correct, therefore no corrections are necessary on these accounts.

The steam is used for running one engine and two pumps, also for heating a large building.

On some cold mornings it is necessary to heat by steam for three hours before the engine is started, after which steam is used for both heating and power purposes. In the afternoon it may be required for power alone, but these varying conditions do not make the slightest difference with the boilers, for they develop 1 horsepower for each 33.5 pounds of water pumped into them throughout the day.

Take a condensing plant where the pressure carried is 140 pounds, the total heat of which is 1,224 heat units and the temperature of the feedwater is 160° F. Then, $\frac{1,110 \times 30}{1,224 - 160} = 31.3$ is the constant for this plant.

The foregoing should make it plain that we can tell how much power is developed by the boilers, without knowing anything about the engine, or even knowing whether there is an engine in the plant or not.

The number of square feet of heating surface required in different boilers to develop 1 horsepower cannot be told arbitrarily, as the type of boiler and other conditions effect the results. An ordinary tubular boiler will evaporate 2 pounds of water per hour for each square foot of heating surface, which is all that should be required. A water-tube boiler will evaporate 2.5 pounds, thus calling for 15 square feet of heating surface in the former and 12 in the latter, per horsepower.

This rate of evaporation is greatly exceeded in some cases, but is not recommended.

USEFUL IDEAS

HEAVY TIMBER JOINTS

A correspondent from Selby, Cal., sends in the following: In looking over the June, 1901, issue of Science and Industry, I notice an inquiry, and its answer, regarding the cut of the toe of a brace or strut. Inquiry No. 250, page 280. The subject recalls a bit of information which I received three or four years ago from a man who has devoted nearly all his time to the framing of heavy structures.

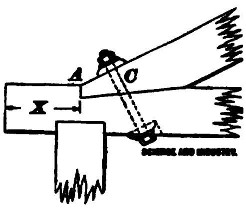


Fig. 1

The plans to which we had to work were unusually detailed and showed strut toes as in Fig. 1. But when we came to do the work on the ground the toes of the struts were made as in Fig. 2 according to the instructions of the foreman.

The advantages claimed were, as regards A and A', that A' gives a more substantial bearing than A, in that it is perpendicular to the line of force and that it tends to distribute the thrust over more area than A, owing to the slope of the surface which receives the thrust, the idea advanced being that the thrust was distributed more in the direction of the dotted line E than horizontally.

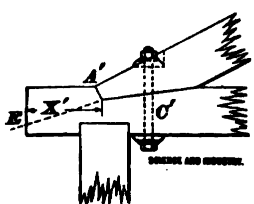


Fig. 2

The other advantage claimed was as regards the positions of the bolt as shown by C and C', position C' being considered superior to C in that the bolt does not draw the toe of the strut away in tightening up the bolt. It was claimed that the bolt is for the purpose of holding the timber in place, not of taking the thrust.

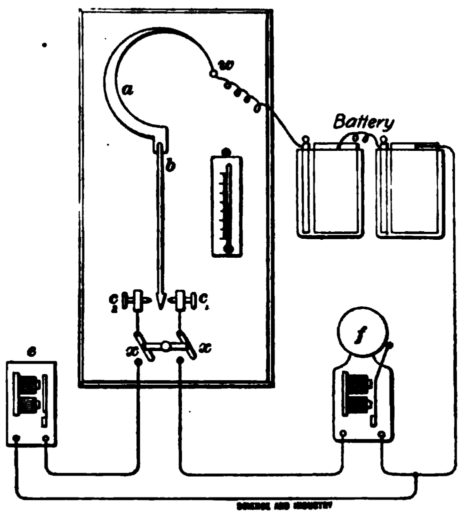
I have never entirely believed in the second advantage claimed for A', but I do believe the claims for C' are correct.

This is not exactly a "query," but I thought that it might possibly be of interest to some reader who is engaged in this same class of work.

HEAT-REGULATING DEVICE

H. F. Pressey

I have noticed in two recent editions of Science and Industry descriptions of heat-regulating devices. The accompanying sketch illustrates a heat regulator which I have in my house and which works well, we being able to keep the temperature uniform.



The hoop a is made of a strap of brass $\frac{1}{32}$ of an inch in thickness and 8 inches long and a thin strip of soft steel $\frac{1}{32}$ of

an inch thick and 8 inches long. These two are soldered together with hard solder and bent, making a hoop 3½ inches in diameter.

Below this is a strip of brass *b* $\frac{1}{32}$ of an inch thick and 5 inches long. This brass strip is soldered to one end of hoop, as shown in the illustration, with good soft solder.

The strip makes contact at c_1 or c_2, ringing a bell or operating a buzzer and calling attention to the fact that the temperature is not right.

e is the buzzer and *f* is the bell.

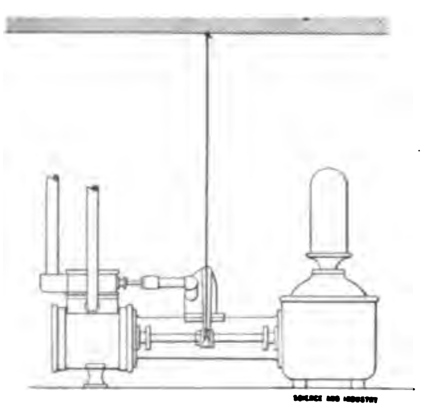
w is a pin which the hoop is soldered to, keeping it in position.

x x is the switch which is used in turning off the current after a contact has been made at c_1 or c_2. After the temperature has risen or fallen, the switch can be turned on.

This device is a very cheap one to make, and any one with any mechanical ideas can easily construct it. It is easily regulated by watching the thermometer and regulating the contact screws accordingly.

AN ENGINE-ROOM CONVENIENCE

One of our subscribers sends in the following suggestion to enable an engi-



neer in a crowded engine room to observe the action of his pump from any part of the room. As will be seen from the illustration, the idea is to simply run a piece of cord from some point of the piston rod to a hook in the ceiling directly overhead. If the engineer happens to be in some part of the room where he can not see the pump, he can, by looking at the cord, tell whether or not it is running and form a pretty good idea of the speed.

INSULATOR FOR PLIERS

Beffenger Foxwell

Procure a piece of circular loom flexible conduit that will fit the handles of your pliers tightly; a piece of ⅜-inch loom is about right for the ordinary 6-inch pliers. Before sliding the loom on the handles a small piece of tape should be put on the end of each handle. Slide the loom up on the handles as far as the construction of the pliers will permit; if the jaws of the pliers will not come together after the loom is on, a piece can be cut off the inside of each piece of loom, letting it project beyond the ends of the handles about ¼ of an inch; this space can be filled up with a piece of tape, pushed in hard. After you have put on the loom it should be thoroughly shellaced, especially the ends, to prevent raveling out. This covering is a little harder to put on than a covering of tape, but any one using loom will never use tape again.

HEATING A SOLDERING IRON

One of our correspondents submits the following for our Useful Ideas column: If a tinsmith's copper or soldering iron is heated in a soft or hard-coal fire the sulphur of the coal combines with the tin and "eats" it off the copper. To avoid this difficulty place the copper into a piece of gas pipe, the lower end of which is closed; place in the fire and no trouble will be experienced.

EDITORIAL COMMENT

MARCH SUPPLEMENT

With this number of SCIENCE AND INDUSTRY we issue a supplement consisting of tables for the conversion of American and Metric measures.

The Metric System is coming into use more and more each year in this country, and a handy table of reference such as this will, we think, be found convenient by many of our readers.

Inasmuch as American units are used entirely in the magazine, those of our foreign subscribers who are familiar with the Metric System only will find the tables especially valuable. Persons desiring an extra copy of the supplement can obtain it by remitting five cents to this office.

THE INVENTORS' INSTITUTE

A copy of the following letter, submitted to The Electrical Age, has been received at this office, together with their comment on the same. Realizing the importance of the plan suggested and the good work it would accomplish if put into execution, we are glad to give space to the entire matter in our columns.

The step taken by The Electrical Age is, we think, admirable and one for which they are to be highly commended.

To the Editor of The Electrical Age.

SIR:—I desire to call your attention to a matter which I think has been neglected so far, but which is of sufficient importance to enlist, not only the sympathies, but also the active cooperation of every one interested in engineering.

It has been proved times without number that the great majority of inventors are men without the means to construct or work out personally the purely mechanical details of (and the securing of patent rights for) their ideas, and it has occurred to me that one of the greatest needs of the present day is the establishment of an institution for the assistance of inventors. In other words, an institute, suitably governed, to which inventors could take their ideas without fear of having them pirated, and where models could be worked out (provided the inventions were worthy), and the letters patent secured for them without expense to the inventors themselves.

If you could be the means of establishing such a model shop on a self-endowed basis, I believe that men of national reputation—say, for instance, professors of electrical, mechanical, hydraulic, steam, and other branches of engineering practice in our great universities—could easily be prevailed upon to act as governors and pass upon the inventions submitted to them. To such men as these the inventor could bring his plans without fear. If these plans were adjudged worthy by the board of governors, the shop would construct the model and the legal department of the institution apply for patent rights, thus saving the inventor from pettifogging lawyers and other sharpers who would seek either to steal his invention or to rob him as much as possible in securing his patent.

While this suggestion may not be original with me, it would, if adopted, be the means of doing away with much that is now to be regretted in connection with such matters and would save the inventors, as a class, from a great deal of unnecessary trouble, expense, and even failure from lack of funds.

Just how great the scope of such an institution would be can be determined better in practice than theoretically. I beg to suggest, however, that if you can interest some wealthy men disposed toward public benefactions, you would do more to benefit the most important class of American mechanics than any one else has ever done before. As the advance or progress of science and of the engineering arts is absolutely dependent on the work of the inventor, you can readily see how important a matter it is to secure for the inventor proper means of establishing the validity of his claims.

It is not my idea to make this suggestion as one of pure charity—in fact, to a certain degree it is selfish, inasmuch as helping the inventor would add to the chances of rapid advancement along scientific lines.

I trust that this matter may have your consideration, and hope that you may see your way clear to make at least an attempt to get the opinions of representative men on the subject, many of whom I am sure will think as I do. My own experience has proved all I claim, for while I was poor and unknown, countless obstacles were daily placed in my way.

Very truly yours,
AN OLD INVENTOR.

In regard to this letter The Electrical Age has the following to say:

The letter explains itself and it is only necessary for us to add a few details in order that it may be more generally understood and appreciated. Our correspondent has suggested a plan of such far-reaching influence and importance as to make it, if accomplished, a benefaction of priceless value, and also, as he so well says, the means of putting additional chances of advanecment within the grasp of progressive Americans.

Let us suppose for a moment that the financial part of the purpose has been attained and the money necessary for the successful carrying out of the project secured. There would then be nothing to hinder the erection of a suitable model shop and laboratory, completely equipped in every respect with the proper modern machine tools, lathes, casting, and molding apparatus, drills, stamps, presses, and all the paraphernalia of such a works, the whole being operated by electric power.

In connection with such a shop thus maintained under the care of a capable foreman, would be offices for the board of governors, who would meet at stated intervals and consider the plans and ideas of inventors who would come before them at such times. To such men the inventor could come and lay bare his heart without fear, and with the knowledge that his ideas would receive most careful attention by the best scientific minds in the country. After all the other necessary steps had been taken and the patent secured, the Institute would influence capital for the exploitation and marketing of the new invention.

In order the more efficiently to propagate this idea and the better to have its great utility generally understood, The Electrical Age will devote in its next two issues all the space required, for letters and contributions expounding the matter at length. We are in a position to state that if the right plan is developed by this competition the money needed for the plan will be forthcoming.

Besides the letters and arguments thus invited, The Electrical Age hereby offers four prizes of $100, $75, $50, and $25, respectively, for the three best articles dealing with the scope such an institution should have and going into reasonable details as to its mission, government, operation, departments, conduction, and maintenance. No article should be of more than 3,500 words in length, and every article submitted in this contest must be received in this office by March 1, 1902. The winners will be announced in an early issue and the awards made at the same time. The judges, whose names will be announced later, will be men of national standing and reputation. The contestants for these prizes must prepare their essays in accordance with these rules, and such manuscripts should be typewritten on one side of the paper only.

The following letter, together with a copy of the patent referred to, has been submitted to us with the request that we publish it. While not desiring to enter into any controversy on the subject, in view of the fact that the writer seems perfectly sincere in his position and is willing to offer abundant evidence in support of the correctness of his statements, it seems only just that we should give the letter the same publicity that we did the article to which it refers.

SCRANTON, PA., February 8, 1902.

Editor Science and Industry,
Scranton, Pa.

DEAR SIR:—In looking over your issue of November, 1901, we notice an able and instructive article by Mr. G. H. Waltman, on the subject of "The Steam Engine Indicator."

We beg to state that, in our opinion, some portions of this article are calculated to mislead your readers and injure our business.

The instrument shown and described in the article as the Roberteon-Thompson, discloses features which were invented by the writer, and which are broadly covered by

the Lippincott patent No. 648,506, under date of May 1, 1900. The improvements referred to are only authorized for use in connection with the Excelsior and Improved Howard-Thompson indicators made by us, and there has never been any assignment of any interest in this patent, to any manufacturer, whereby these improvements may be used in connection with any instrument except those named above, and our understanding is that any one who makes or uses an infringement is liable for an action to recover damages and royalties.

It is plainly our duty to publicly inform prospective purchasers of our patent claims, in order that they may not unwittingly become liable to a suit. Furthermore, the writer has devoted many years to the exhaustive study of this subject, and has expended large sums of money in experiment and in perfecting his line of indicators, reducing wheels, and planimeters, and he should not be deprived of the fruits of these efforts.

We enclose you herewith a copy of the patent referred to above, and will cheerfully furnish a copy to any of your readers who desire to carefully investigate the matter. We also enclose an engraving of the Excelsior Indicator, equipped with our improvements, including the removable quarter-inch area cylinder and piston, used for very high pressures.

Thanking you in advance for your attention to the matters referred to above, we are, Very truly yours,

UNION STEAM SPECIALTY CO.,
By A. C. LIPPINCOTT, Manager.

BOOK NOTICES AND CATALOGUES

PRACTICAL MARINE ENGINEERING. By W. F. Durand, Professor of Marine Engineering at Cornell University, author of Resistance and Propulsion of Ships, etc.; pages 6 × 8 inches; illustrations with index; complete series of questions, etc. Published by Marine Engineering, New York. Price, $5.00.

The book here offered to those interested in steam engineering, as applied to marine work, is intended to be thoroughly practical, and is designed to do something more than to merely fit an engineer to secure his first papers, or to squeeze through an examination for higher papers.

Questions and answers are of value in certain cases and for the presentation of certain classes of facts, but they do not aid the applicant for an engineer's license to use his brains and to reason for himself upon the subjects under discussion.

In this respect Practical Marine Engineering is intended to supply the necessary facts, and to aid the reader to think for himself. Each topic is illustrated in detail, and the descriptive matter is very fully explained by reference to drawings taken from representative examples of recent practice.

In addition to the constructive side, special attention is given to subjects of operation, management and care, casualties, repairs, etc.

A special chapter is given to the discussion of various problems of importance for the marine engineer. Some of these are elementary, while others include topics which will be of interest to those already familiar with elements of the profession.

The features above referred to will be found in Part I of the book. In Part II will be found a simple and comprehensive presentation of the mathematical operations required in ordinary engineering work. This is intended as an aid to the student of the subject, who has not had opportunities for advanced education, and includes a discussion of the usual numerical operations; algebraic signs and symbols, formulas and their use, geometry, mensuration, elementary mechanics, physics, etc., with explanations of the computations most commonly used by the engineer, and with numerous illustrative examples and problems for the student.

Throughout the entire book, and especially in the chapter on special problems, will be found numerous illustrative examples worked out in detail, and accompanied by like problems for the exercise of the student.

LIGHT, HEAT, AND POWER IN BUILDINGS. By Alton D. Adams, Member American Institute of Electrical Engineers. One 12mo. vol., cloth; 102 pp. Price, $1.00. New York, W. T. Comstock.

This book is intended as a convenient manual on the subjects treated, its object being to present in compact form the main facts on which selections of the sources for light, heat, and power in buildings should be based. In the discussion of the subject

questions of economy and efficiency are very fully considered, and the requirements of equipment to suit different conditions dwelt on. While scientific theories are referred to, yet the purpose is rather to make practical suggestions that will be applicable in actual practice, than to enter upon theoretical discussions as to the merits of various classes of apparatus. The feature of special interest in the work and its main novelty, that of arrangement by cost of service from widely different sources, are set down side by side.

This feature of the work is one that will be appreciated by architects and others who wish to study the essential features of plants of this character for their buildings. It will be found a useful and ready reference for such purposes.

VELOCITY DIAGRAMS. By C. W. MacCord. Published by John Wiley & Sons, New York. Price, $1.50.

Through his former works on descriptive geometry, kinematics, and mechanical drawing, Prof. MacCord has already become familiar to those interested in mathematical literature, and his present work is fully up to the standard heretofore set by him.

Among the subjects treated in the book are, the construction of velocity space, velocity time, angular velocity, and velocity-ratio diagrams, and their use in comparing different movements, and the determination of acceleration by a process of graphical differentiation.

The principles of the more common and convenient graphic processes of determining at any given instant the direction and velocity of the motion of a point, whether that motion be constant, or variable, are clearly explained.

The chapter on velocity-ratio diagrams seems to be particularly well written, setting the matter forth in such a clear manner as to be easily comprehended by any one at all familar with the elementary principles of mechanics.

The book is gotten up in the well-known style of John Wiley & Co., is profusely illustrated, and is one which we can unhesitatingly recommend to our readers.

ARCHITECT AND BUILDER, 8 Ledger Building, Philadelphia, Pa., is a magnificently illustrated magazine, with fine, full-page, half-tone cuts on bristol board. A sample copy can be had for 25 cents.

A HAND BOOK FOR APPRENTICED MACHINISTS. Edited by Oscar J. Beale. Published by Brown & Sharpe Mfg. Co., Providence, R. I.

This little book, as the title indicates, is for the benefit of those who are learning the machinists' trade. Among the subjects it treats are: care of machines, centering, turning, reading drawings, measuring, lacing belts, drilling, counterboring, tapping, cutting speed, screws, figuring gear and pulley speeds, change gears for screw cutting, setting a protractor, working to an angle, circular indexing, straight-line indexing, and subdividing a thread. The chapters on gears and indexing are especially valuable, and could well be read by many machinists long out of their time.

The information throughout is given in a clear, concise, and eminently practical manner, and is accompanied by numerous illustrations. To any one at all familar with machine-shop work, the practical value of the book is very apparent.

The Christensen Engineering Co. have sent us their catalogue and instruction book on the Christensen Automatic Air Brake, manufactured by them. They are both well illustrated and the instruction book contains a complete set of drawings, showing the method of operation and of attaching the brake to the car, piping, etc. There is also a diagram showing the operation of the valves.

We are in receipt of Catalogue No. 29 of the A. S. Cameron Steam Pump Works, New York, N. Y. The catalogue gives illustrations and descriptions of the pumps manufactured by them.

We have received Catalogue No. 13 of the Kempsmith Mfg. Co., Milwaukee, Wis., descriptive of the millers made by this concern.

We are in receipt of "Yankee" Tool Book No. 4, published by North Bros. Mfg. Co., Philadelphia, Pa. The book is neatly gotten up and contains illustrations and descriptions of the screw drivers, drills, chucks, etc., manufactured by this enterprising concern.

The Joseph Dixon Crucible Co. have gotten out a neat little booklet containing testimonials of their automobile graphites.

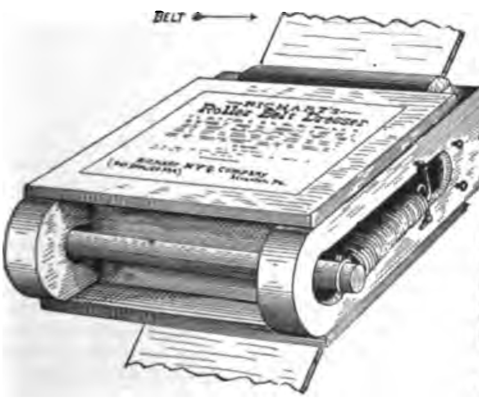
TRADE NOTES

The steel tapes made by the Lufkin Rule Co., of Saginaw, Mich., are frequently tested by Uncle Sam's experts. Discrepancies between these tapes and the standard have indeed been found, but they were expressed in decimal fractions so small as to be meaningless to the layman, and of no practical importance to engineers, accustomed as they are to mathematical hair splitting.

To understand the work of the Lufkin Rule Co. it is scarcely needful to remind readers of this journal that a steel tape is as sensitive as an exposed nerve in a tooth. It is affected by changes of temperature which even a sick baby would not feel. A cold finger or a warm breath makes a difference in it.

Yet the Lufkin tapes are made of steel so excellent and uniform in temper and are graduated with such nicety, that the makers feel warranted in giving a guarantee of accuracy. That this confidence is shared by engineers and teachers of engineering has been abundantly proved. When you stop to think of it, the dependence of mechanical art upon a thin ribbon of graduated steel appeals strongly even to a dull imagination. The Lufkin tape is more than a mere article of commerce. It is a valuable contribution to the branches of industry which do most for the material and intellectual progress of society.

The accompanying illustration shows a very ingenious device, recently patented, for dressing a belt. It consists of a wooden



box containing a rectangular cake of grease and having a roller at one end. Springs attached to a rod at the other end hold the grease cake firmly against the roller, and as the cake wears off, the springs can be moved up so that nearly the entire cake can be used. By holding the roller up against the belt with sufficient tension to cause it to revolve it engages the bar of grease from the inside of the case, rubbing the grease off from the cake and depositing it in a thin, even film on the belt. The grease is made up in cakes to fit the box, and a special kind of dressing is made for rubber and cotton belting. The machines are manufactured by the Richart Mfg. Co., of Scranton, Pa.

California Art and Nature, published monthly at No. 868 15th Street, San Diego, California, announces as a gift by C. R. Orcutt, of that city, of more than 100,000 specimens of natural history, of shells, minerals, plants, etc. (mostly collected in California by C. R. Orcutt and with printed labels), to the schools and colleges of the United States, and the distribution will soon commence to those complying with the simple conditions of the gift, intended to promote the establishment of free museums in every public school. One hundred varieties of shells, etc., will be given every institution that applies that now has or wishes to have a museum.

California Art and Nature is a beautiful illustrated magazine, published monthly at 20 cents a copy or $2 a year; about 100 half tone and wood engravings, and 12 colored plates, will ornament volume one. Art and Nature Co., 868 15th Street, San Diego, California.

The Joseph Dixon Crucible Co., Jersey City, N. J., give interesting information concerning the protective painting of the Union Railroad Bridge, which crosses the Monongahela River at Pittsburg (Rankin), Pa.

Designed for carrying molten metal from the Carrie Furnace to the steel mill and raw materials to the furnaces, this notable steel structure is subjected to heat from the molten metal, sulphur fumes from locomotives and river steamers, also from the adjoining furnaces and steel mills.

No other steel bridge in all the world is exposed to so many and severe destructive agencies. The best metal preservative was necessary, and the eminent engineers selected for its protection Dixon's Silica-Graphite Paint, as manufactured by the Joseph Dixon Crucible Co.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

We must again caution our readers sending in inquiries, to carefully observe the rules at the top of this column.

In inquiry No. 450 in the December, 1901, number, we stated that we did not know of any states where architects were licensed. We have since learned that on July 1, 1897, a law was passed in the State of Illinois requiring architects to pass an examination and procure a license before being allowed to practice, and that this law is rigidly enforced.

MECHANICAL

(49) (*a*) I have a 22 in. × 48 in. Corliss engine cutting off at ⅜ stroke. The steam valves having a lead of ⅛ inch, about how much exhaust lead is required? (*b*) I wish to make a center-punch mark on the shaft 90 degrees ahead of the crank. How shall I proceed? (*c*) I have had a discussion with several parties as to whether the lead does not change with the point of cut-off in automatic cut-off engines. Will you enlighten me on this subject?

G. T., Petoskey, Mich.

Ans.—(*a*) We think that if you set the exhaust valves so they will open when 44 inches of the stroke have been completed, you will get satisfactory results. (*b*) We presume you wish to place the mark on the surface of the shaft between the eccentric and flywheel. First of all place the crank on a dead center, it does not matter whether it be the head-end or the crank-end dead center. The next step is to scribe a line on the shaft that will be in the same plane as the center line of the shaft and the center line of the crank. Now take a machinists' surface gauge and place it in some convenient position near where the mark is desired and where the bent point of the scriber can reach the top and bottom of the shaft. Set the gauge so that the bent point will touch the top of the shaft. Swing the pointer clear of the shaft without moving the gauge away from its position, and from some convenient fixed point measure vertically upwards to the end of the bent point. Turn the point 180 degrees in its socket; set it to touch the bottom of the shaft; swing the gauge around again and measure vertically upwards again. Add the two measurements and divide their sum by 2. Now set the scribing point to the quotient just obtained, measuring vertically upwards again from the same point as before. The scribing point of the surface gauge has now been set to lay in the horizontal plane containing the center line of the shaft, and assuming the engine to be horizontal, and level, to be in the plane containing the center line of the shaft and crankpin. Scribe a line on the shaft, defining it well by a center-punch mark. The easiest way to obtain a mark 90 degrees from this, is to multiply the diameter of the shaft at the point where the mark is located by 4, and then to cut a narrow strip of thin paper to the calculated length. Place one end of the strip on the mark just made; wrap the strip around the shaft, and at its other end make a mark defining 90 degrees ahead of the crank. (*c*) This depends entirely on the design of the valve gear. In releasing gear engines with pendulum governors, as the Corliss type, the lead does not change with the point of cut-off In shaft-governor automatic cut-off engines this depends entirely on the design. Some governors shift the eccentric so that the lead remains constant throughout the whole range of cut-off; other governors shift the eccentric so that the lead decreases with an increase in the cut-off, and others so that it increases with an increase of cut-off, or conversely, decreases as the cut-off is made earlier. In any case, it can readily be found by analysis what effect a change of cut-off has on the lead by plotting the eccentric motion and the motion of the valve on the drawing board.

(50) Please inform me if there is a book published giving all the points in regard to building gasoline engines. If so, what is the book? F. A. S., Newark, N. J.

ANS.—We think that the best book for your purpose is one entitled "Gas Engine Construction," by H. V. A. Parsell. Price $2.50. This can be obtained from the Technical Supply Co., Scranton, Pa.

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(51) (*a*) Where can I obtain a book on saw hammering? (*b*) What is the best method of speeding machinery?
W. H. C., Vancouver, B. C.

ANS.—(*a*) We do not know of any book on this subject. (*b*) See question No. 435, in the December, 1901, issue of this magazine, for explanation of this subject.

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(52) (*a*) I would like to know if hoisting engine valves are set so the feed remains open almost the entire stroke or equal to the exhaust? (*b*) Has anything on this subject been published in SCIENCE AND INDUSTRY? W. P. F., Columbia, S. C.

ANS.—(*a*) Hoisting engine valves are set to cut-off before the end of the stroke. (*b*) We have not published any articles pertaining directly to this subject.

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(53) (*a*) Please give me the correct formula for counting the speed of a duplex pump. (*b*) What is the best book on the care and operation of a refrigeration and ice-making plant? J. H., Retreat, Pa.

ANS.—(*a*) The speed of a duplex pump is expressed by the number of strokes made per minute by both pistons. (*b*) We can recommend the following books on this subject: "Refrigerating and Ice-Making Machinery," by A. J. Wallis Taylor. Price $3.00. "The Practical Running of an Ice and Refrigerating Plant," by Paul C. O. Stephansky. Price $2.00. "Refrigeration and Ice-Making and Refrigerating Machinery," by W. H. Wakeman. Price 25 cents. All of these books can be obtained from the Technical Supply Co., Scranton, Pa.

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(54) (*a*) Please give me an illustration and description of a piston valve. (*b*) Please give me some information concerning the Ohio State Board of Examiners for engineers. (*c*) Do railroad companies hold their own examinations or are they held by some board, and are applicants for positions examined on the air brake and signals?
E. A. A., Haney, Ohio.

ANS.—(*a*) See answer to question No. 353 in the October, 1901, issue of SCIENCE AND INDUSTRY. (*b*) All engineers in charge of or operating steam plants of more than 35 horsepower in the State of Ohio are required to have a license to do so. The State is divided into six districts, there being six district examiners, and examinations are held at any time and place, as the district examiners have a regular schedule and are on the road nearly all the time conducting these examinations, which are both oral and written as the needs of the case require, due notice being given the engineers by mail or otherwise of the time and place of such visits. The fee for examination and issuing of license is $2.00, and the fee for renewal thereof yearly is $1.00. (*c*) Railroad companies examine their own applicants for positions and require a knowledge of the air brake and signals, as well as of the locomotive.

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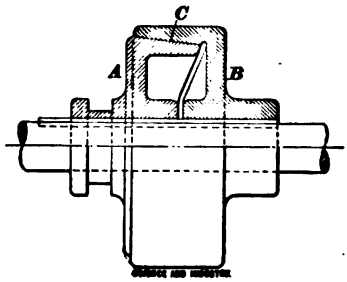
(55) Please give me an explanation of the friction clutch. S. L. D., Carlisle, Pa.

ANS.—We illustrate here one of the simplest types of friction clutches. It consists of two parts, *A* and *B*, the latter of which is keyed to the driving shaft, and the other to the driven shaft. The part *A* is attached so that it can be moved to throw the surfaces at *C* in or out of contact. These surfaces taper sufficiently so that by forcing the two together, enough friction is created to drive the driven shaft, but not enough to cause them to stick when it is necessary to separate them. The movable part *A* is



operated by means of a clutch lever and mechanism which will insure a perfect contact when the clutch is "thrown in" and cause a free separation when it is thrown out. More serviceable and more intricate friction clutches are on the market, some of which are advertised in the columns of engineering papers. Makers are always glad to furnish complete descriptions of these. A very interesting clutch was described in "Power" of June, 1901.

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(56) How will the most mud be taken out of a boiler, by blowing off with a low pressure or without any pressure?
W. M. C., Carlisle, Pa.

ANS.—The boiler should be blown out each day while the pressure is on. A good time to do this is early in the morning before the sediment has been much stirred up by

the circulation of the water. At intervals, depending on the character of the feedwater, the boiler should be entirely emptied and washed and scraped clean of sediment and scale.

***

(57) Please give me the true definition of a horsepower. W. K. E., Westminister, Ind.

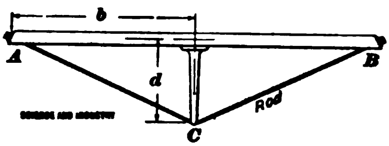
ANS.—The horsepower is a unit of power. Power is the rate of doing work and is determined by dividing the work done by the time which it takes to do it. The commonly accepted standard of horsepower is the power of a strong London draft horse for doing work for a short interval. This was measured and found equal to 33,000 foot-pounds. By 33,000 foot-pounds we mean an amount of power that will raise 33,000 pounds 1 foot in 1 minute, or that will raise 1 pound 33,000 feet in 1 minute.

***

(58) Please explain how to find the stress on the truss rod $B\,C$ for any given load applied on the horizontal member $A\,B$, as in the sketch below.

P. G., Cape Breton, N. S.

ANS.—For a load of w pounds per foot distributed uniformly over the horizontal



member $A\,B$, the stress in the truss rod $A\,C$ or $B\,C$ will be the tension equal to $\frac{5\,w\,b}{8\,d}\sqrt{b^2+d^2}$, in which b denotes one-half the span $A\,B$ and d denotes the depth of the truss, the measurements being from center to center. For a single load W, concentrated at the center over the vertical member, the stress in the truss rod will be equal to $\frac{W}{2\,d}\sqrt{b^2+d^2}$. For other conditions of loading the expression for the stress in the truss rod would be too complicated to be given here.

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(59) (*a*) A wire rope 800 feet long and 1 inch in diameter is stretched between two towers and inclines at an angle of 14°. The weight of the rope will cause a certain amount of sag, and I should like to know the formulas for finding the safe weight that may be carried on the rope, and the proper sag for such a span. When tightening the rope how can I tell when it has arrived at the proper sag to support a certain load? (*b*) Can you recommend a book on this subject, and also one on the detailing and installation of Babcock & Wilcox boilers? (*c*) Where can I get "Molesworths' Pocket Book of Engineering," and what is the price of it?

M. C. R. T., Funchal, Madeira.

ANS.—(*a*) In order to answer these questions satisfactorily, we should have to have more data than you give. When in possession of full information as to existing local conditions, it is not a difficult matter to figure out such a system as this, and if you will furnish us with more complete data we shall endeavor to give you the information you desire. We would recommend, however, that you correspond with the Trenton Iron Co., of Trenton, N. J., U. S. A. They have made exhaustive experiments in regard to wire-rope tramways and have installed a large number of plants of this sort. Their catalogue, which will be sent you on request, contains formulas and information which will enable almost any one to make the calculations which we believe you desire. (*b*) You can also obtain some information on this subject from a book entitled "Transmission of Power by Wire Ropes," by A. W. Stahl. Price 50 cents. We know of no book devoted exclusively to the Babcock & Wilcox boiler. One of the best books on the subject of boilers in general that we know of is one entitled "Boilers and Furnaces," by Wm. M. Barr. Price $3.00. We would recommend that you correspond with the makers, the Babcock & Wilcox Co., 85 Liberty St., New York, N. Y., U. S. A. (*c*) The price of this book is $2.00. You can obtain all the books herein mentioned by addressing the Technical Supply Co., Scranton, Pa., U. S. A.

ELECTRICAL

(60) (*a*) Why is a helix always placed at the terminals of the wires before attaching to the binding posts of a bell? (*b*) What is the advantage of grounding the spark coil instead of the batteries in electric gas lighting? (*c*) According to the B. & S. wire gauge, No. 10 wire carries 20 amperes and No. 14, 10 amperes. Could not a line of 40 lamps in multiple be wired with No. 10 wire, by connecting the positive and negative feed-wires as shown. and have 10 amperes flow in each direction? (*d*) Do the same number of amperes flow back on the negative wire as are taken from the positive wire when lights are run in multiple?

W. T. S., Winthrop, Mass.

ANS.—(*a*) This is done more for appearance than anything else. The helix has nothing to do with the working of the apparatus. It is placed there to take up the spare wire or to allow a small amount of spare wire in case the bell has to be shifted.

(*b*) There is no particular advantage that we know of. As long as the spark coil is inserted in series with the battery, it makes very little difference where it is placed. (*c*) If you fed in at the center of your mains, and had 20 lamps distributed on each side, the current on each side of the junction would be 10 amperes, and the current in the wires would be 20 amperes, so that No. 10 would be large enough to supply the current. (*d*) Yes; the current flowing back to the negative side is the same as that flowing out at the positive side.

***

(61) What causes the bolts that hold the copper bars on the short-circuiting rings of an induction-motor armature to pull out and break off?

W. F., Howes Cave, New York.

ANS.—There is a strong pull on the bars due to the interaction between the magnetic lines of force set up by the coils on the stationary frame and the magnetic lines of force set up around the conductor bars on the armature, caused by the current in these bars. The position of the bars in the slots should prevent motion of the bars. The trouble may be caused by expanding and contracting action due to temperature changes of the armature. In a well-designed motor the bolts should be strong enough to withstand this pull unless the motor is very heavily overloaded.

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(62) I am constructing an electrical machine having two glass plates which revolve in opposite directions, one of which is excited by a horse-hair cushion. (*a*) Will you please inform me what kind of leather should be used for covering this cushion? (*b*) How is the amalgam mixed? I have tried muriatic acid but it would not cut the mercury. (*c*) How is the solution prepared for plating nickle? (*d*) Give directions for making a sealing compound for dry batteries?

E. L. L., Hudson, Mass.

ANS.—(*a*) Sheepskin works well; place the soft side (flesh side of leather) out. (*b*) Take equal parts, by weight of zinc and tin; melt them together and, while molten, mix in twice their weight of mercury. The amalgam is applied to the cushion with a little stiff grease. (*c*) Dissolve 12 to 14 oz. of double sulphate of nickle and ammonia in one gallon of water. The nickle salts (double sulphate of nickle and ammonia) are put into a wooden tank and hot water poured on them till they dissolve. The solution is then poured into the plating tank. As this solution has a fairly high resistance, it is a good plan to add about 10 per cent. of common salt. This makes a whiter and tougher deposit of the metal. (*d*) Cook together, for several hours, equal parts of rosin and paraffin.

(63) In regard to the sparking dynamo described in the July, 1901, number of SCIENCE AND INDUSTRY, I would like to inquire: (*a*) How many armature disks are used, also their thickness and material? (*b*) How is the armature wound?

S. S. W., Haverhill, Mass.

ANS.—(*a*) The disks are made of well annealed sheet iron or steel, anywhere from .015 to .025 in. in thickness. The number of disks will, of course, depend on the thickness of the iron, and all that is necessary is to use a sufficient number so that they will form a core 2½ in. long when they are clamped firmly between the end plates, as shown in the drawing of the armature core. (*b*) See Answers to Inquiries, January 1902, No. 18.

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(64) In the July, 1901, number of SCIENCE AND INDUSTRY, answer to inquiry 272, you describe the construction of a small transformer. (*a*) Will you kindly tell me what changes are necessary to construct same for primary voltage of 10 or 55, and secondary of 10 or 5 volts? (*b*) How many watts does it consume? (*c*) What current can be had from the secondary?

C. D. O., Manlius, N. Y.

ANS.—(*a*) For primary voltage put about 400 turns of No. 18 B. & S. wire on each coil. For secondary use about 38 turns of No. 10 B. & S. wire on each coil. (*b*) About 100 to 125 watts. (*c*) About 10 amperes with coils in series and 20 amperes with coils in parallel.

***

(65) I am about to construct a 10 or 12-inch spark coil for medical use; would you kindly tell me what would be the best size to make the coil and what would be the best sizes of wire to use for the primary and secondary circuits? Should there be a condenser in the circuit, and if so, what kind is best? Would a Western Electric 5.2 M. F. condenser have capacity enough? How should the interrupter be connected up and how much battery should be used? I have 50 volts in battery. How should they be connected to get the best results? If it does not take up too much space, would you kindly give me a diagram of spark-coil circuit? What is the best book on spark coils and the price of the same?

A. D., St. Louis, Mo.

ANS.—It would take more space than we have at our disposal to answer all of the above and give diagrams of connections. We think your best plan would be to procure a book on the subject, and we would recommend "Induction Coils," by H. S. Norrie (Norman H. Schneider). This is a new book and it describes the various methods of constructing coils. The price of the book is $1.00. Technical Supply Co., Scranton. According to this authority, the following

dimensions are suitable for a 12-inch coil: Core, 19 inches long by 1½ inches diameter; primary No. 10 B. & S., 2 layers of wire; secondary No. 38 B. & S., 12 pounds; condenser, 60 sheets of tin foil, 12 in. $\times$ 8 in., with alternate sheets of paper, 10 in. $\times$ 14 in. The core is made up of No. 22 B. W. G. wire. In order to get the best results, the condenser should be adjustable.

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(66) (*a*) I understand that electric heaters heat water very slowly. I would like to know about how long it will take a 100-watt electric heater under the best conditions to completely evaporate 1 gallon of water. (*b*) Has the earth a great or small resistance when used as part of a circuit?

R. H. M., Akron, Ohio.

ANS.—(*a*) Electric heaters heat water slowly simply because they give out a small amount of heat as compared with ordinary heat sources, unless a large amount of electrical energy is used. To boil a given amount of water requires the same expenditure of heat energy no matter whether the heat is obtained from an electric heater or other source. If we assume that no heat is lost through radiation, or, in other words, that all the energy put into the heater goes into the water in the form of heat, it would take about 27 hours for a 100-watt heater to convert 1 gallon of water into steam. In practice it would take longer than this, because some of the heat would be lost to the surrounding air. If the water were simply to be heated to the boiling point and not converted into steam, the heater would accomplish it in 4½ hours, assuming that no heat were lost. (*b*) This depends very much on the nature of the earth contacts. It has been found that most of the resistance occurs at the contacts, and that the distance between the earth plates can be increased considerably without greatly affecting the resistance. For small currents, such as are used in telegraphy and telephony, the resistance of the earth may be taken as negligible; but with large currents, as used in connection with street railways, the earth cannot be depended on as a conductor.

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(67) (*a*) Please describe fully the manufacture of 110-volt, 16 c. p. incandescent lamps. (*b*) Who invented them? (*c*) How long will one burn if burnt continually? (*d*) What causes them to burn out? (*e*) What causes sparks to encircle the commutator of a motor that is running freely?

E. C. F., Philadelphia, Pa.

ANS.—(*a*) It would take far more space than we can spare in these columns to describe the manufacture of incandescent lamps. The light-giving filament is made of carbonized cellulose and it is attached to small, platinum, leading-in wires that carry the current through the glass. After the filament has been sealed in, the air is exhausted by means of a small tube attached to the end of the bulb opposite the base, and after the air has been fully exhausted, this tube is melted off. (*b*) The invention of the incandescent lamp is not probably due to any one person, but Edison deserves the credit of bringing it to such a state of perfection that it could be used commercially. (*c*) This depends so much on the quality of the lamp and the steadiness of the voltage on the circuit that no definite figure can be given. Under ordinary conditions, however, a lamp should last 800 to 1,000 hours. Many of them last much longer, but a lamp that has been burned a long time is very inefficient. (*d*) The filament gradually disintegrates and finally breaks. Lamps are also often broken by high voltage on the line, and in other cases the vacuum in the lamp may be defective. Defects in the filament often leads to breakage, even when the lamp has burned but a comparatively short time. (*e*) Sometimes particles of dirt or carbon dust on the commutator will cause this. Try wiping the commutator with a piece of canvas. If the sparks are very bright and resemble a ring of fire, causing burning of one or more of the bars, the chances are that there is an open circuit somewhere in the armature.

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(68) Please inform me whether copper or German silver wire should be used to make a small electric heater? I have a 110-volt circuit and want to make a heater to take about 2½ amperes. I also want to make a small heater to operate on 80 volts and take 3 amperes. Please inform me as to the quantity of wire and the size required in each case. R. C., Annapolis, Md.

ANS.—German silver should be used as the resistance of copper is not high enough for this purpose. The 110-volt heater will have a resistance of 44 ohms, and the 80-volt heater 26.6 ohms. If you bed the wire in some non-conducting material, such as cement, it will be safe to use the sizes as follows: For the 110-volt heater, use 350 feet No. 19 B. & S., and for the 80-volt heater, 250 feet of No. 18. Wires as small as this could not be used safely if they were mounted in the open air.

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(69) (*a*) I recently connected up a general electric motor on a 500-volt power circuit. The motor ran nicely for a few hours, then began flashing badly and blew both fuses. I tested with lamps for cause of trouble, and found machine grounded by having been set upon damp boards too near the earth. The machine was raised up 3 inches and set on dry pine planks. A second test was made and no ground could be found between the earth and any of the conductors on the machine. Could

this trouble have happened without a second ground? (*b*) How are cross-connections and short circuits most successfully located in closed-coil armature windings? (*c*) How can the direction of rotation of the armature of a motor or dynamo, whose brushes are direct bearing, be determined by the position of the connections on the headboard? (*d*) What is the ohmic resistance per horsepower? (*e*) Does a dynamo lose its residual magnetism so that it has to be excited by some source of direct current? (*f*) What is the resistance of the human body? (*g*) How many volts does it take to kill a person? (*h*) Is not an alternating current more dangerous to life than any direct current when grounded through a person?

L. D., Lansing, Mich.

Ans.—(*a*) We take it that the power circuit you refer to was a metallic return one, and not a ground-return circuit as used in connection with an electric railway. Such being the case, two grounds would be necessary to produce a short circuit, and it is quite possible that in this case there may have been another ground somewhere on the line. (*b*) The bar-to-bar test is the one generally used for locating open circuits and short circuits in these armatures. You will find this method described in an article entitled "Repair-Shop Armature Testing," in Science and Industry for July, 1900. (*c*) Unless you have blueprints or diagrams supplied by the makers, the direction of rotation cannot be predetermined by an inspection of the terminal connections. It depends on the direction of winding of the armature, and also upon the winding of the field coils, and these cannot usually be determined by a mere inspection. (*d*) This question is not clear. There is no fixed ohmic resistance corresponding to a given horsepower of a motor. The horsepower output of a motor is given by the expression $\text{H. P.} = \frac{\text{current} \times \text{E. M. F.}}{746 \times \text{efficiency}}$. Motors of the same horsepower output might have quite different values for the ohmic resistance of their armatures. (*e*) A dynamo sometimes loses its residual magnetism, though under ordinary conditions it should not. In case it does, it is necessary to recharge the fields from some outside source of current. (*f*) The resistance of the human body varies greatly with the condition of the skin at the contact surfaces. It may vary all the way from 10,000 to 300 ohms, according to S. P. Thompson. The average resistance is probably about 2,500 ohms. (*g*) The voltage necessary to cause death depends very largely on the physical condition of the person receiving the shock. From 1,000 to 2,000 volts is sufficient if applied for a short interval, though persons have been killed with lower pressures than this. 3,000 volts will cause instant death. (*h*) An alternating current, of given voltage, is more dangerous than a direct current of the same voltage, because the maximum value which the alternating voltage reaches is much higher than the direct-current voltage of equal average value. The reason, however, why alternating currents are more dangerous in practise than direct currents is simply because they are used at very much higher pressures than direct currents.

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(70) (*a*) Please inform me how to construct and operate a selenium cell. (*b*) What will be the cost of the cell? (*c*) What other metals or chemicals have been used to transform light energy into electrical energy?

N. S. P., Mt. Vernon, New York.

Ans.—(*a*) A simple form of selenium cell may be formed by winding two separate spirals of platinized silver wire around a cylinder of hard wood. The two wires are kept a short distance apart. The space thus formed between the two wires is filled with fused selenium, which is allowed to cool gradually. The end of one wire forms one electrode, and the end of the other wire forms the other electrode. Current passes across from one wire to the other through the selenium. A cell may also be be formed by placing the fused selenium between the edges of brass plates and allowing it to harden in this position, thus forming a narrow strip of selenium between the edges of the plates. Selenium cells are temporarily reduced in resistance if exposed to light. Connect a selenium cell in series with a small battery and a telephone receiver, and allow the selenium cell to be alternately exposed and protected from some source of light. The variations in the resistance of the selenium cell will be noted by the sounds made in the telephone receiver. A selenium photometer may be constructed by which the intensity of a given light may be estimated by the changes in the resistance of a selenium cell, which is exposed to this light, and then exposed, under similar conditions, to a standard light. A selenium cell will produce a light when one end of the cell is exposed to light and the other end darkened. If a wire is connected between the ends, a current will flow from the darkened end to the exposed end. (*b*) We do not know the cost of construction of these cells, but presume that a small cell could be constructed at a reasonable expense. (*c*) A cell composed of two plates of silver, coated with freshly deposited chloride of silver, which are placed in a glass jar of water, will generate a slight E. M. F. if one plate is exposed to light and the other plate darkened. (*c*) Quite a number of metals seem to be acted on by radiant energy under certain conditions. We would suggest that you read the experiments of Hertz on electrical phenomena of this nature.

(71) Will you kindly inform me how I can make joints in the lead strips which connect the plates in a storage battery? The battery is in an automobile, and the lead connecting strips have come apart near the surface of the liquid and outside of each cell on top. Appearances indicate that joints have been made there before. We have never succeeded in fastening them so that they will hold. What is the reason that they come apart, and is it possible to make a joint that will stand the acid and current? F. S. H., Hammond, Ind.

ANS.—Joints of this kind in connection with storage batteries are nearly always made by "burning" the parts together. The lead parts are fused together by using a hydrogen flame, and no solder is employed. If solder is used, it is soon attacked by the acid and the joint becomes useless. It may be that the joints were not well burned together in the first place, and that the continual jarring caused the defective ones to give way. Very often such joints are imperfectly made, the connection being good only at the surface of the metal.

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(72) Please advise me how to set up an Edison-Lalande battery so as to furnish a current. E. J., Chicago, Ill.

ANS.—The copper oxide plates are placed in the frame which hangs between the two zinc plates. The zincs should be well amalgamated by first dipping them in dilute sulphuric acid and then rubbing them over with mercury. The solution is made up by dissolving 30 to 40 parts, by weight, of caustic potash in 100 parts of water, and enough solution should be placed in the jar to come well up over the copper oxide plates. After the solution has been placed in the cell, heavy paraffin oil should be poured on top of it so as to form a layer about ¼ inch in depth. If this oil is omitted, air will get at the solution, and the formation of a carbonate will greatly reduce the life of the cell. If it is desired to have the cell deliver a current at once, it should be short-circuited for 10 or 15 minutes after first setting up; but under ordinary working conditions, it should not be short-circuited. The initial short-circuiting reduces enough of the copper oxide to render the cell active.

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(73) In one of the lessons on Alternating Currents it is stated that if a direct current were connected to a condenser and an ampere meter placed in the circuit, the needle would deflect for a second or so. Then, as soon as the circuit was broken, the deflection would be in the opposite direction. Now, I cannot understand this. If electricity is a kind of wave motion, where does the current come from that flows back? I can see nothing in the condenser to cause a current, but I know it to be a fact. S. T., Houston, Texas.

ANS.—When a condenser is connected to the direct-current mains, the plates of the condenser become charged and a stress is produced in the material between the plates. When the wires are connected, a momentary current flows until the pressure between the plates becomes equal and opposite to that of the line. Now, suppose the condenser to be disconnected entirely from the line, the two terminals being kept apart. The plates will still be charged, and there will still be a stress in the dielectric between the plates, and the charge on the plates with its accompanying stress would remain there indefinitely if there were no leakage. If, however, the terminals are brought together, the charges are at once neutralized and a momentary reverse current flows between the plates, at the same time relieving the stress in the material between the plates. In other words, when a condenser is charged, a certain amount of energy is stored up by the stress produced in the static field between the plates, and as soon as there is a chance for the condenser to discharge, it does so, and this energy is given back. It is the same case exactly as when a spark is obtained from a Leyden jar that has been charged by a static machine.

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(74) (*a*) Please explain what causes the general clicking of telegraph instruments. (*b*) I hear that there is some preparation by which, if put on glass, a hole can be made as easily as through iron; do you know what this is? (*c*) What flux can I use to solder iron with an ordinary soldering copper, and how should the iron be prepared? (*d*) Do you know of a good waterproofing material for leather; a cheap one? S. T., Houston, Texas.

ANS.—(*a*) The clicking of a telegraph instrument is caused by the striking of the lever of the instrument against one of the limiting stops. The lever of a telegraph instrument usually has attached to it a thin, flat piece of iron, called the armature, and when a current starts to flow through the coils of the telegraph instrument this armature is suddenly attracted, thereby causing the lever, to which the armature is fastened, to strike against a limiting stop screw. When the current ceases to flow through the coils, the armature is suddenly released and a spring immediately draws the lever back, thereby causing it to strike against another limiting stop screw. This ordinarily happens about 5 times per second, giving 10 clicks per second. Hence, if there are a number of instruments working in the same room, there is apparently nothing but a confused clicking; however, each operator listens only to his own instrument, the signals

of which he can readily read by their relative lengths. (*b*) A hole can be readily drilled through glass in the following manner: For a drill use an ordinary piece of brass pipe, having the desired outside diameter. When drilling the hole constantly feed a mixture of emery and turpentine upon the surface of the glass being drilled. It is best to frequently raise the pipe so that the mixture can work under the end of the pipe. This may not be the exact preparation that you have heard of, but it will do the work all right. (*c*) Ordinarily a solution of zinc chloride, commonly known as "soldering acid," will answer your purpose. The iron should be thoroughly scraped and cleaned, using the acid in the latter process, and then well tinned. In some cases, we believe, the iron is first given a very thin coat of copper by electrolysis, or by wiping or dipping the iron in a solution of copper sulphate. It can be soldered more easily. (*d*) Neat's-foot oil is the best preservative we know of for leather. If the pores of the leather are filled with this oil water will not be absorbed.

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(75) (*a*) How can hall lights be wired so as to be controlled by switches at two points? (*b*) What size of dynamo need be installed, to be driven by wind power, to charge a storage battery that is to furnish current for ten 16-candlepower incandescent lamps?
W. B. M., Roland Park, Md.

Ans.—(*a*) For an illustrated article on the "Control of Incandescent Lamps From Two or More Points," we would refer you to the April, 1900, number of this magazine. (*b*) A 1½-horsepower dynamo would probably be of sufficient size. The size of dynamo would depend somewhat upon the strength and continuity of the prevailing winds. See article in the "Electrical World" of June 10, 1893, in regard to descriptions of existing plants of this kind.

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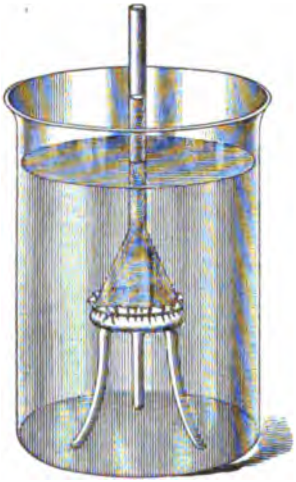
(76) I have several sets of batteries; one set of 4 cells for an elevator annunciator, one set of 3 cells for 40 call bells for speaking tubes, and a third set of 3 cells for a private annunciator. Some days these batteries will give a strong current, and the next day so weak a current that the bells will hardly ring, but in the latter part of same days they build up and again give a strong enough current. For 2 or 3 days after being recharged they give a weak current, then build up, and are all right for a week or two. Please give remedy, if any. J. W. N., Boston, Mass.

Ans.—You are requiring too much work from your batteries. You should double the number of cells in each circuit by connecting another row of exactly the same number and kind of cells in parallel with each set. This should improve matters considerably. The continual use of the cells some days runs them down; then, if they are not used very much for awhile, they recover and work all right until they are again used too much. It is natural that they should not work very vigorously right after receiving new charges; however, we see no reason for this lack of strength lasting as long as 2 or 3 days. When you recharge, use fresh solution only—throw all the old away—and thoroughly clean the zincs and carbons.

MISCELLANEOUS

(77) Please explain osmotic pressure and tell me where I can obtain reports of experiments on this subject.
F. M. W., Baltimore, Md.

Ans.—Osmotic pressure may be defined as the pressure that a dissolved substance exerts upon the solvent. In explanation of this definition we will say, that experiments have proved that many dilute solutions behave as if the dissolved substance were present in a condition independent of the solvent, and that the molecules of a dissolved substance exert a pressure on the



solvent identical with the pressure which they would exert on the sides of the vessel, of the same volume as that of the solution, if they were in the gaseous state, and that this discovery gave rise to a "physical theory" of dilute solutions which is generally stated as follows: The molecules of the dissolved substance pervade the solvent without being influenced thereby, and possess the same properties as they would possess did they alone, in the gaseous state, occupy the volume filled by the solution. The osmotic pressure of a substance dissolved in water is determined by means of

membranes which allow the passage of water, but not of a substance dissolved in it, through them. This property is found in animal protoplasmic membranes and in porous substances covered with an amorphous precipitate, such as is obtained by the action of copper sulphate on potassium ferrocyanide. If, for instance, a glass tube, wide at the mouth and covered with a membrane, be partly filled with a solution and placed in a vessel containing a proportionally large amount of water, as shown in Fig. 1, the volume of the liquid in the tube will usually show either an increase or a decrease. With a 1 per cent. solution of potassium carbonate, sodium phosphate, cupric chloride and many other substances, there is a rapid increase in the volume and the column would rise to a considerable height; but with oxalic acid, the mineral acids, stannic chloride, etc., a fall in the liquid would be observed, and finally, with colloidal substances only slight alteration occurs. Solutions which exert equal osmotic pressure are said to be isotomic. This subject is more fully treated in books on physical chemistry.

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(78) (*a*) At what angle should the braces be set in a framed house? (*b*) Some claim that the braces in a framed house should extend from the sill to the upright, while others, that it should extend from the upright to the plate; which is correct? (*c*) Are saws or edged tools injured by being left in the sun when the thermometer registers from 100° to 110° in the shade. (*d*) What is the difference, if any, in effect on the human body of chemical electricity and magneto electricity? R. S. L., Runge, Texas.

Ans.—(*a*) The best angle at which to frame braces is 45°, for at this angle the brace is the shortest, and, as it is subjected to compressive stress, is more rigid and less liable to spring and buckle. (*b*) It is preferable to place the braces between the uprights and the plates, for by this means greater security against lateral motion at the second floor joists is secured. (*c*) While heating and slow cooling is apt to anneal steel and destroy the temper of the tools, it is hardly possible that the temperature named in the inquiry would have any appreciable effect. Slow cooling from temperatures of 300° to 400° successively applied would seriously affect the temper of the tools. (*d*) There is no difference provided the magneto electricity is uniform. Some magneto machines give a pulsating or varying current that causes irregular muscular contraction, whereas the current from a battery is perfectly steady. If, however, the dynamo providing the current, has a large number of commutator segments, its current becomes practically uniform and will produce the same effects as a battery current, assuming, of course, that the same voltage is applied in each case.

(79) As we are planning a large trade school here, I would like to know the usual fees of an architect for designing and looking after such a building.
J. L. L., Hanover, Va.

Ans.—The minimum charge made by architects in good standing with the profession is 5 per cent. on the entire cost of the job. This charge of 5 per cent. is usually itemized somewhat as follows: 1 per cent. for preliminary sketches and studies; 2½ per cent. for plans, elevations, detail drawings, and specifications; 1½ per cent. for superintending the construction. On all work besides United States Government work the architect usually charges and receives any traveling expenses he may have incurred in the execution of the work. Where the architect is called upon to design small work, such as furniture, mantels, etc., he usually charges according to the time required to make the designs and drawings, and does not attempt to make a percentage charge.

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(80) Some time ago you published an article on the art of joint wiping. Can I obtain a copy of the issue containing same.
F. K., Pittsburg, Pa.

Ans.—This article was published in the November, 1899, number of Science and Industry, a copy of which you can obtain by remitting 10 cents to this office.

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(81) I am troubled with leaks in cast-iron and semi-steel ammonia fittings. The metal is porous and the ammonia comes through it. I have tried to solder by using muriatic acid, but I cannot get the solder to hold. Kindly inform me how I can solder same so as to make the solder hold.
M. B., San Francisco, Cal.

Ans.—We would recommend that you submit the fittings to a bath of shellac under pressure. This will tend to fill up the pores in the metal and prevent the ammonia oozing through it.

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(82) Where can I get a book on how to make sleds, toboggans, and skies?
E. R., Rico, Colo.

Ans.—We think you can obtain information on these subjects in "The American Boys Handybook." The book dealer in your town can probably obtain it for you.

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(83) Please inform me where I can get a copy of "Grant's Treatise on Gears."
E. E. C., Ft. Wayne, Ind.

Ans.—You probably refer to "Gearing," by Geo. B. Grant. This can be obtained from the Technical Supply Co., Scranton, Pa. Price $1.00.

Tables for Converting American and Metric Measures

AMERICAN TO METRIC | METRIC TO AMERICAN

LINEAR

	Inches to Millimeters	Feet to Meters	Yards to Meters	Miles to Kilometers		Meters to Inches	Meters to Feet	Meters to Yards	Kilometers to Miles
1 =	25.4001	0.304801	0.914402	1.60935	1 =	39.3700	3.28083	1.093611	0.62137
2 =	50.8001	0.609601	1.828804	3.21869	2 =	78.7400	6.56167	2.187222	1 24274
3 =	76.2002	0.914402	2.743205	4.82804	3 =	118.1100	9.84250	3.280833	1.86411
4 =	101.6002	1.219202	3.657607	6.43739	4 =	157.4800	13.12333	4.374444	2.48548
5 =	127.0003	1.524003	4.572009	8.04674	5 =	196.8500	16.40417	5.468056	3.10685
6 =	152.4003	1.828804	5.486411	9.65608	6 =	236.2200	19.68500	6.561667	3.72822
7 =	177.8004	2.133604	6.400813	11.26543	7 =	275.5900	22.96583	7.655278	4.34959
8 =	203.2004	2.438405	7,315215	12.87478	8 =	314.9600	26.24667	8.748889	4.97096
9 =	228.6005	2.743205	8.229616	14.48412	9 =	354.3300	29.52750	9.842500	5.59233

SQUARE

	Square Inches to Square Centimeters	Square Feet to Square Decimeters	Square Yards to Square Meters	Acres to Hectares		Square Centimeters to Square Inches	Square Meters to Square Feet	Square Meters to Square Yards	Hectares to Acres
1 =	6.452	9.290	0.836	0.4047	1 =	0.1550	10.764	1.196	2,471
2 =	12.903	18.581	1.672	0.8094	2 =	0.3100	21.528	2.392	4.942
3 =	19.355	27.871	2.508	1.2141	3 =	0.4650	32.292	3.588	7.418
4 =	25.807	37.161	3.344	1.6187	4 =	0.6200	43.055	4.784	9.884
5 =	32.258	46.452	4.181	2.0234	5 =	0.7750	53.819	5.980	12.355
6 =	38.710	55.742	5.017	2.4281	6 =	0.9300	64.583	7.176	14.826
7 =	45.161	65.032	5.853	2.8328	7 =	1.0850	75.347	8.372	17.297
8 =	51.613	74.323	6.689	3.2375	8 =	1.2400	86.111	9.568	19.768
9 =	58.065	83.613	7.525	3.6422	9 =	1.3950	96.874	10.764	22.239

CUBIC

	Cubic Inches to Cubic Centimeters	Cubic Feet to Cubic Meters	Cubic Yards to Cubic Meters	Bushels to Hectoliters		Cubic Centimeters to Cubic Inches	Cubic Decimeters to Cubic Inches	Cubic Meters to Cubic Feet	Cubic Meters to Cubic Yards
1 =	16.387	0.02832	0.765	0.35242	1 =	0.0610	61.023	35.314	1.308
2 =	32.774	0.05663	1.529	0.70485	2 =	0.1220	122.047	70.629	2.616
3 =	49.161	0.08495	2.294	1.05727	3 =	0.1831	183.070	105.943	3.924
4 =	65.549	0.11327	3.058	1.40969	4 =	0.2441	244.093	141.258	5.232
5 =	81.936	0.14158	3.823	1.76211	5 =	0.3051	305.117	176.572	6.540
6 =	98.323	0.16990	4.587	2.11454	6 =	0.3661	366.140	211.887	7.848
7 =	114.710	0.19822	5.352	2.46696	7 =	0.4272	427.163	247.201	9.156
8 =	131.097	0.22654	6.116	2.81938	8 =	0.4882	488.187	282.516	10.464
9 =	147.484	0.25485	6.881	3.17181	9 =	0.5492	549.210	317.830	11.771

WEIGHT

	Grains to Milligrams	Avoirdupois Ounces to Grams	Avoirdupois Pounds to Kilograms	Troy Ounces to Grams		Milligrams to Grains	Kilograms to Grains	Hectograms (100 Grams) to Ounces, Av.	Kilograms to Pounds, Av.
1 =	64.7989	28.3495	0.45359	31.10348	1 =	0.01543	15,432.36	3.5274	2.20462
2 =	129.5978	56.6991	0.90719	62.20696	2 =	0.03086	30,864.71	7.0548	4.40924
3 =	194.3968	85.0486	1.36078	93.31044	3 =	0.04630	46,297.07	10.5822	6.61386
4 =	259.1957	113.3981	1.81437	124.41392	4 =	0.06173	61,729.43	14.1096	8 81849
5 =	323.9946	141.7476	2.26796	155.51740	5 =	0.07716	77,161.78	17.6370	11 02311
6 =	388.7935	170.0972	2.72156	186.62089	6 =	0.09259	92,594.14	21.1644	13.22773
7 =	453.5924	198.4467	3.17515	217.72437	7 =	0.10803	108,026.49	24.6918	15.43235
8 =	518.3914	226.7962	3.62874	248.82785	8 =	0.12346	123,458.85	28.2192	17.63697
9 =	583.1903	255.1457	4.08233	279.93133	9 =	0.13889	138,891.21	31.7466	19.84159

CAPACITY

	Fluid Drams to Milliliters or Cubic Centimeters	Fluid Ounces to Milliliters	Quarts to Liters	Gallons to Liters		Milliliters or Cubic Centiliters to Fluid Drams	Centiliters to Fluid Ounces	Liters to Quarts	Decaliters to Gallons	Hectoliters to Bushels
1 =	3.70	29.57	0.94636	3.78544	1 =	0.27	0.338	1.0567	2.6417	2 8375
2 =	7.39	59.15	1.89272	7.57088	2 =	0.54	0.676	2.1134	5.2834	5 6750
3 =	11.09	88 72	2.83908	11.35632	3 =	0.81	1.014	3.1700	7.9251	8.5125
4 =	14.79	118.30	3.78544	15.14176	4 =	1.08	1.352	4.2267	10.5668	11.3500
5 =	18.48	147.87	4.73180	18.92720	5 =	1.35	1.691	5.2834	13.2085	14.1875
6 =	22.18	177.44	5.67816	22.71264	6 =	1.62	2.029	6.3401	15.8502	17.0250
7 =	25.88	207.02	6.62452	26.49808	7 =	1.89	2.368	7.3968	18.4919	19.8625
8 =	29.57	236.59	7.57088	30.28352	8 =	2.16	2.706	8.4534	21.1336	22.7000
9 =	33.28	266.16	8.51724	34.06896	9 =	2.43	3.043	9.5101	23.7753	25 5375

COMPLIMENTS OF SCIENCE AND INDUSTRY, SCRANTON, PA.

SCIENCE AND INDUSTRY

Vol. VII April, 1902 No. 4

LINING UP AN ENGINE

TO THE wideawake mechanic and engineer an occasional lull in business activities becomes a busy time, because all kinds of machinery after running continuously for perhaps a year or even less will require more or less "doctoring," and the dull periods whenever they occur offer excellent opportunities to do this kind of work. In the engine room we find more work to be done than in almost any other department. The more important work usually consists in lining up the engine, filing and fitting brasses, cleaning journals, setting up piston packings, and putting the main driving belt in good order. In the boiler room we have the work of scaling the boilers, repairing the furnaces and settings, repacking joints and pumps, and a general cleaning out. This involves a variety of operations, and in a plant of even 100 horsepower it represents a good week's work and oftentimes even more for two competent men. None of the work previously mentioned requires more skill and care than lining up the engines and filing the brasses and fitting them to the pins.

If "lining up" is needed, the engine will usually have indicated something wrong, sometimes by hot journals, or peculiar pounds which cannot be cured by taking up lost motion, and by unequal wear in various parts. If the connecting-rod has some side motion, it will usually slap against the crank at certain points in its revolution, and it will be found that this slapping noise cannot be cured by taking up lost motion either at the wrist or crank-pins without producing a hot pin. Sometimes the crosshead and guides will run hot, which is quite an unusual occurrence when an engine is in line, or the piston rod may heat considerably, so that the packing must be left very loose, frequently producing a leak, in order to save the packing from burning. The piston rings will quite often click or rattle to such an extent that one would think that they had at least a quarter of an inch clearance, although in reality it may prove to be a scant one-hundredth, which, of course, would be sufficient when fitting rings. These and many other symptoms, in different engines, would lead an engineer to believe that his engine was out of line; and well it may, for in seven cases out of ten where they occur to any considerable extent the engine will be found to be badly out of line.

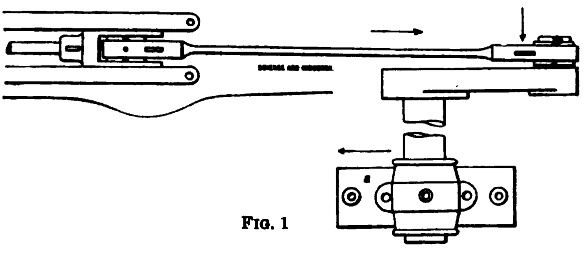


FIG. 1

The cause of the connecting-rod slapping against the crank (or the collar), and the reason why it cannot be cured by driving the key or raising the wedge in the rod, as the case may be, may be understood by referring to Fig. 1. This represents a portion of the crank-shaft, the crank and crankpin, and the

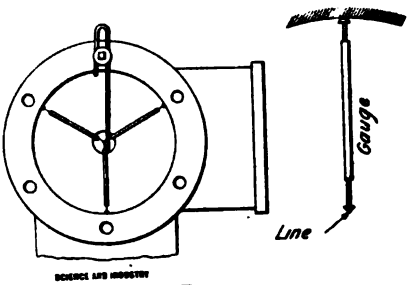


FIG. 2

connecting-rod. The crank-shaft is out of line, which throws the crankpin out of line also. While the drawing represents a somewhat exaggerated case, it will serve to illustrate the fact that when the rod is forced outward in the direction of the arrow the brasses do not bear squarely against the pin, or if they have gradually worn down to a bearing, the center line of the connecting-rod will not be at right angles to the center line of the crankpin, and the tendency will be to force the rod against the crank, and at the opposite end of the connecting-rod we find the tendency is to push the crosshead to one side, which causes the shoes to bear harder against one side of the guides than the other, especially with a short rod. If the engine has a light load, this one-sided action may not cause heating, but the guides and the crosshead shoes will be found to wear away faster on one side than the other. When this process has continued long enough, the piston rod will be found to travel very close to the gland and the side of the hole through the head; the packing will be squeezed too tightly on one side and will not be tight enough on the other, and one of two evils will result, namely: either the gland must be left very loose, oftentimes producing a leaky stuffingbox, or the packing will become overheated and ruined. The face of the packing rings in the piston will not be parallel to the cylinder walls, and in a short time they will have become worn, which will give rise to the clicking and rattling referred to. Tightening the brasses will not prevent the rod from moving sidewise, as will be seen in the drawing.

When the crank-shaft is not exactly at right angles to the axis of the cylinder, it gives rise to perhaps a dozen troubles, none of which can be cured in themselves. Any attempt to cure them individually would be too local to have a lasting effect, and so there is nothing left but to remove the cause, in other words, to put the engine in line. The crank-shaft is liable to get out of line "both ways," as it is called, that is, it is liable to be out of line vertically as well as in a horizontal direction.

First procure a piece of stout cord or a wire of small diameter, and about

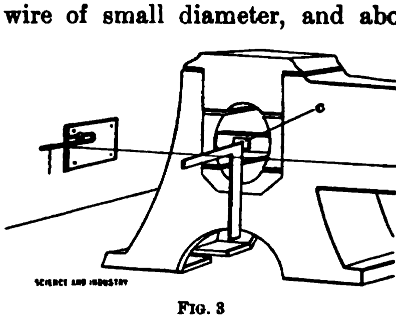


FIG. 3

6 feet longer than the engine. Remove the cylinder head at the head end of the engine and then construct a line holder as shown in Fig. 2. Of course, it need not be of this form, although a bar held by one of the studs permits ready adjustment and has proved to be a very convenient arrangement.

A second holder should be placed at the foot of the engine, as shown in Fig. 3, which may be attached to a board nailed to the wall. Then disconnect the piston rod from the crosshead, pull out the piston and take down the connecting-rod; then slip the crosshead out of the guides and remove the gland from the stuffingbox.

If the engine is comparatively small the shaft can be removed, but if a large engine it had better remain in place. Attach the wire or cord to the holder at the head end, pass the other end through the cylinder and stuffingbox and attach it to the opposite holder. Inside calipers are not always a convenient tool for this work, particularly for those unfamiliar with their use, and if this proves to be the case, the gauge shown in Fig. 2 may be found convenient and is easily made. It consists of a piece of pine of small diameter into each end of which is driven a common pin, as shown. The length of the gauge is, of course, equal to one-half the diameter of the cylinder, less one-half the diameter of the line. The line is now to be brought into the center of the cylinder by

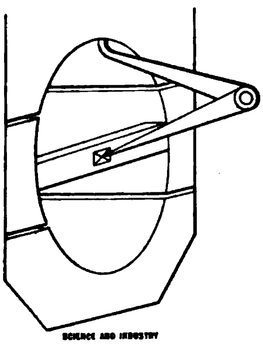


FIG. 4

means of the gauge, as shown in Fig. 2, trying the gauge at three points in the circumference of the cylinder and at each end of the bore. After centering the line, adjust the height of the crank-shaft in the following manner, if it is an engine from which the shaft can be removed. Take a piece

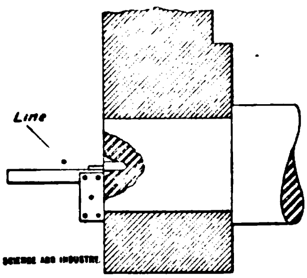


FIG. 5

of wood about 1½ inches wide by ½ inch thick and tack on a piece of tin at the middle. Drive this piece of wood in across the bearing and flush with the end, as shown in Fig. 4. Chalk the tin, and then by means of a pair of calipers, as shown in the same figure, the exact center of the bearing may be found and a very light punch mark made in the tin. Now take a square; place one leg against the end of the bearing so that the point of the square *c* comes over the punch mark (see Fig. 3). The distance the horizontal leg of the square lies below the line shows how much the shaft has worked down and how much it must be raised in order to be in line vertically.

When the engine is large and it becomes impracticable to remove the shaft, file a piece of wire to the form shown in Fig. 5, and by the aid of a piece of tubing drive it into the center in the shaft, as shown in the same figure. This should be done the day before shutting down, so that in case the point does not run true it may be adjusted and tried while steam is up. The line in this case is to be put through the cylinder in precisely the same manner as previously described,

seeing that the crankpin is below the center line of the engine.

When "squaring up," place the square so that it touches the under side

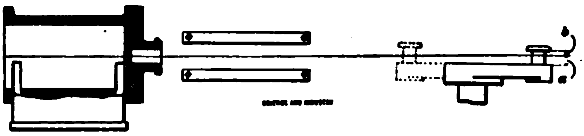


FIG. 6

of the fine point, as shown in Fig. 5, when the distance the shaft must be raised may be measured between the line and the horizontal leg of the square as before. After raising the shaft by placing liners under the bottom box (which should be of uniform thickness and of the same size as the under side of the box), the shaft must be leveled, for the outboard bearing will probably have worn down somewhat also and must be raised by means of liners, put in in a similar manner. After leveling the shaft, the engineer will be prepared to adjust its position horizontally. To do this, have the

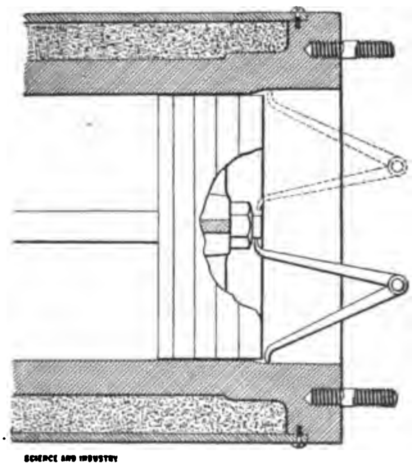


FIG. 7

shaft (replaced if taken out) turned carefully until the crankpin just touches the under side of the line, but not hard enough to raise it. Measure the distance *a* and *b*, Fig. 6. If there is any difference between the two distances, have the outboard bearing moved slightly until these distances are equal. Then have the crankpin brought up to the line near the opposite center (indicated by dotted lines) and again measure the distances *a* and *b*, when they will probably be the same; if so, the shaft will be in line horizontally, that is, the center line of the shaft will then be on the same level and at right angles to the center line of the engine. It may happen that the distances *a* and *b*, Fig. 6, will not be the same when the crankpin occupies both positions, which may be due to wear at the crank-boss or at the collar on the pin if the engine is an old one. In this case the distance *a* and the distance *b* should be the same on both sides of the shaft, that is, when the pin occupies either center. For instance, if *b* measures $2\frac{1}{2}$ inches and *a* $2\frac{7}{16}$ inches when the crank occupies the position shown by the full lines in Fig. 6, then *b* should measure $2\frac{1}{2}$ inches and *a* $2\frac{7}{16}$ inches when the crankpin is in the position shown by the dotted lines. In Fig. 6, this would not be the case until the outboard bearings were moved in the opposite direction to that indicated by the arrow shown in Fig. 1. The effect of moving this bearing, upon the position of the crankpin, can be readily understood by an inspection of the drawing, Fig. 1, which represents the shaft as badly out of line.

The guides come next, and if of the movable type they are adjusted to their proper position sidewise by calipering the distance between their inner surface and the line at various points in their length.

Take down the line and put in the piston, and center it by calipering

with a pair of calipers similar to those shown in Fig. 7. If the piston has adjustable packing rings, the follower plate should be taken off, when the rings may set out and the piston centered by means of the adjusting screws provided for this purpose.

The piston should be centered before attempting to adjust the rings, particularly when they are of the sectional variety. When centering the piston it is generally better (except in the case of very old cylinders needing reboring) to use the counter bore instead of that part of the cylinder traversed by the piston, as illustrated in Fig. 7. First loosen the jam nuts *a*, *b*, and *c*, Fig. 8; then set out the calipers under the end of the piston rod as indicated. Do not use the face of the nut as a bearing point for the calipers. After getting the distance between the under side of the rod end and the counter bore, try them above the rod, one-half the distance between the leg of the calipers and the rod end indicating the distance the rod should be raised. Lay aside this pair of calipers and with another pair ascertain whether the piston rod is in the center of the cylinder sidewise. This is done to save time, because if the piston must be moved sidewise as well as upward it can frequently be placed just right by turning only one of the side screws, either *b* or *c*, depending on whether the piston is to be moved respectively to the right or to the left as well as upward. If the piston rod is to be simply raised, then only the central screw *a* need be turned, and should this be the case, take up the first pair of calipers and with the wrench turn the screw *a* a little and try the calipers; then give the screw another turn and again try the calipers, continuing in this manner until the rod has been raised so that the calipers just "feel" the rod. Try the calipers under the rod to see that it has not been raised too high; then try them at the sides, because the calipers ought to feel the rod at both top and bottom and at either side when the rod occupies a perfectly central position. Now set out the screws *b* and *c* until they touch the bull ring, and if the piston rings need setting out this is the proper time to do it. See that all jamb nuts are properly tightened before placing

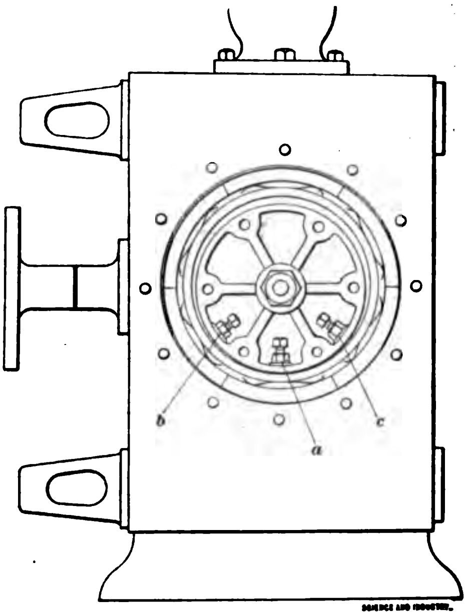


FIG. 8

the follower plate in position. It is a good plan to smear a little graphite on the follower bolts before screwing them in. This does not add to the tendency to work loose, but it does make it much easier to remove them next time. When tightening the follower bolts, tighten each one a very little, after they have been screwed in up to the head, going around and around the plate four or five times before having them screwed home. This method insures a more equal tension on the bolts, and hence they are not as likely to work loose.

The cylinder head may now be put on. Next slip on the gland and put the crosshead between the guides and connect it to the piston rod. We are now ready to adjust the height of the guides, or the height of the crosshead if the engine has a girder frame. Push the piston against one head and mark the position of the crosshead on the guides; then push it against the opposite head and make a similar mark at that end of the guides. These marks are to be made in a straight line on both the crosshead and guide, and are known as the striking points, to be used later on. Now place a straightedge across the guides near one end, as shown in

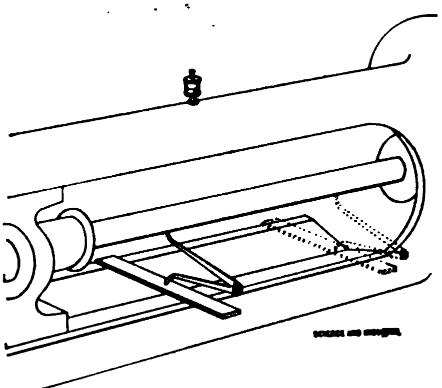


Fig. 9

Fig. 9, and caliper the distance between it and the rod and repeat this operation at the opposite end; the difference between these distances represents approximately the amount the guides (or the crosshead, if a girder-frame engine) must be raised. The distance between the rod and the guide (bottom guide) should be the same at all points in the stroke. The top guide or the top crosshead shoe, as the case may be, may then be adjusted to a nice working fit. When the piston rod is badly worn, the distance between the rod and the bottom guide will not be the same at all points in the stroke, particularly near the outer end, and in this case the calipers must be placed several inches from the crosshead in order to get a point where the wear has been more uniform, taking the measurements at both ends of the stroke, as before.

The connecting-rod is now put on and the crank placed on either dead center. Measure the distance between the mark on the crosshead and the striking point. Repeat this operation at the opposite end of the stroke, when the crank occupies the exact dead center. If these distances are not equal and differ to the extent of an eighth of an inch or more, they should be equalized by placing liners behind the brasses in the connecting-rod, or adjusting the piston rod if it is screwed in the crosshead. After packing the piston rod, and moving the crank off the dead center, the engine will be ready to run, and if any pound occurs which cannot be cured by taking up the lost motion, it will be due to the engine having been out of line, in which case the remedy will be a local one, affecting the noisy parts individually. The filing and fitting of brasses in order to remove these pounds will be taken up in our next issue.

STEAM-BOILER INSPECTION

THE following article which appeared in the Scientific American of February 22, will, we think, be of interest to many of our readers in that it will help to enable them to discover for themselves defects which may exist in boilers under their care:

It is only in the presence of a fatal and destructive explosion that the public fully appreciates the tragic possibilities that are wrapped up in every one of the two or three hundred thousand boilers that nestle among the teeming multitudes of our cities, or speed to and fro on steamboats and locomotives. Steam-boiler explosions date from the very first use of steam under pressure, and the records of the early growth of steam engineering are punctuated with many a sad accident due to faults of material or design in the early boilers. With the increase of pressures which came at the time of the introduction of multiple-expansion engines, there was a call for special care in the testing of the materials and in the construction of steam boilers, and there is no doubt that measured against other forms of constructive mechanical work the boiler of today will hold its own on any point of comparison.

If the security of the user stood solely upon the quality of his boiler, and there were no such thing as rapid depreciation due to neglect or unsuspected decay, there might have been relatively but little work for the steam-boiler inspector, and no development of the great steam-boiler insurance companies whose organization and operations mark them as among the most perfect insurance institutions in the world.

The absolute necessity of inspection is so fully realized that in some States, the inspection of boilers is compulsory, and the State provides inspectors for this work. In such cases a fee is charged by the State for the service. In other States, there is no compulsion about inspections; and in all cases, if the boilers are inspected regularly by a boiler insurance company in good standing in the State in question, additional inspection by the State is not required.

In most of the States, locomotives on railroads are expressly exempt from State inspection. It is presumed that the railroad owning the locomotive will provide a master mechanic, or other expert, who will be competent to pass upon the fitness and safety of their locomotives. This presumption does not appear to be altogether realized in practice, for railroad locomotives constitute a class of boilers which explode almost as often as any other class that can be mentioned. Omitting city elevated railroads, the total number of railroad locomotives in the United States on December 31, 1900, was 38,065.

Steamboat boilers are inspected by the United States government, and are therefore exempt from inspection by the State, or by any other authority. For this service the United States government employes sixty-three inspectors of boilers. There are over 7,000 steamers in the deep-sea, coastwise, and river service of the United States.

The total number of stationary boilers now in use in the United States was not ascertained in the last census. Neither are they enumerated in the census of 1890; but the census of 1880 shows that at that time there were 72,304 stationary boilers in this country. It was estimated by The Locomotive that on December 31, 1890, there were approximately 100,000 stationary boilers in the United States.

The same authority estimates that at present there are about 170,000 boilers under insurance.

The methods of inspection adopted by the various companies, though they vary in detail, are carried out upon the same general lines. We have been informed by Mr. J. M. Allen, president of the Hartford Steam Boiler and Inspection Co., that at the present writing this company has 83,907 boilers under insurance, and the system employed may be taken as representative of the best modern practice. The inspection, as such, is devided into three classes: (1) hydrostatic tests, (2) external inspections, and (3) internal inspections.

The hydrostatic test consists in applying a cold-water pressure to a boiler that is completely filled with water. The pressure is usually applied by a pump that the inspector carries with him. The usual test pressure that is applied, hydrostatically, is 50 per cent. greater than the working pressure at which the boiler is run. In Philadelphia, however, the law states that "a hydrostatic test of one-third greater than the boiler is rated to carry" will be considered sufficient.

When the boiler is under hydrostatic pressure, the inspector looks it carefully over, in all parts, to see if there are any signs of leakage, or of distress of any sort. This test is usually applied to new boilers, or to boilers upon which extensive repairs have recently been made, or upon boilers the interiors of which are not accessible, either because of their small size, or for any other reason. In some places, however (notably in the city of Philadelphia), a hydrostatic test is required by law on all boilers. Authorities differ about the advisability of applying the hydrostatic test, some maintaining that it is much better than the "hammer" test, to which we shall presently refer, because the actual pressure may develop a defect that the inspector, armed only with his hammer, might overlook. Other authorities claim that there is danger of straining the boiler by subjecting it to a test 50 per cent. greater than it will ever have to withstand in practice. The hydrostatic test is not considered to be injurious to the boiler, when it is applied by a man with good judgment, but the hammer test is preferable when that can be applied.

"External inspections" are those made by merely looking the boiler over from the outside, to make sure that the attendant is not running it at a higher pressure than is allowed; that he is carrying plenty of water in the boiler; that the safety valve will blow off freely, and at the pressure that is allowed; that the water gauges are in good condition; that the boiler is not showing any signs of leakage, nor any bulges over the fire sheet, nor any signs of distress of any kind. Of course, the attendant is not notified in advance when the company makes an inspection of that kind, for the object of the visit is to see the boiler in the condition in which he usually runs it, without giving the attendant any opportunity to "fix up" for the inspector's benefit.

"Internal inspections," or hammer tests, as they are sometimes called, are made by the inspector entering the boiler through the manhole, and looking the interior over very carefully. He makes a similar examination, also, of the outside of the boiler, crawling into the furnace and all about, everywhere that he can go. Among the things that he has to look out for are these: Deposit of sediment or muddy matter, hard incrustation or scale on the tubes and plates, corrosion of any part of the boiler, both inside and outside, frac-

tures of the plates, heads, headers, etc., leakage around the tube ends, seams, and all other places where such leakage is possible, defective bracing of the flat parts of the boiler, grooving of the plates or heads, burned or blistered parts, and defective accessories of all kinds; water gauges, feed-pipes, blowpipes, safety valves, pressure gauges, and everything else that can get out of order in any way whatever.

As an example of the magnitude and extent of the work of insurance and inspection, it may be mentioned that the company above referred to employs a regular force of 198 inspectors, and in the year 1900 made 92,526 complete internal and external inspections (i. e., "hammer tests"), and in addition subjected 10,191 boilers to hydrostatic pressure; while from the beginning of the company's business down to January 1, 1901, 1,176,097 complete internal and external inspections were made, and enough external inspections to bring the total up to 3,049,203. Also, 162,586 hydrostatic tests were made and 13,215 boilers were condemned as unsafe, good and sufficient reason for the condemnation being given to the owners in every case. During this time there were discovered and pointed out to the owners 2,226,256 defects of one sort and another, 245,210 of which were quoted as dangerous.

It is upon data of this sort that a steam-boiler inspection company bases its claims to be considered as a great public safeguard. We have no way of knowing how many explosions work of this kind may have prevented, nor how many lives it may have saved, but the claim can fairly be made that the total number of lives saved has been great, and that the loss of property that has been prevented has been enormous.

TRANSFORMER PROTECTIVE DEVICES

R. B. WILLIAMSON, M. E.

WHEN efforts were made about 15 years ago to introduce the high-tension alternating current for lighting purposes, it was violently attacked by the advocates of the low-pressure direct-current system, because of the danger of life incidental to the use of the high-pressure current. The wide use of alternating current at very high pressures has since shown that most of the objections formerly made were to a large extent groundless, but every now and then accidents happen, and of late years accidents caused by persons coming in contact with the secondary wires, which are supposed to be harmless, seem to be on the increase. This is no doubt partly due to the fact that alternating current is so much more widely used than formerly, but it is a question if some of them are not due to the use of old transformers that have been in service for many years without ever being tested as to their insulating qualities. The writer has in mind two or three accidents which happened within the last year, where persons were killed by touching a lamp socket on the secondary of alternating-current systems.

In most accidents of this kind death is due to the fact that the high-pressure direct-current wires in some way or other come in contact with the secondary wires that lead into the consumer's premises. Such a connection is generally made by a breakdown of insulation between the primary and secondary coils of the transformer. It may also be due to a direct contact

between the primary mains and the secondary mains outside of the transformer, but this condition does not occur so frequently, because the run from the secondary to the consumer's premises is usually short and direct.

Fig. 1 will serve to illustrate the condition referred to above, where a breakdown in insulation has occurred between primary and secondary. *P* and *S* are the primary and secondary coils, which, under ordinary conditions, are thoroughly insulated from each other; *m*, *n* are the secondary wires leading to the lamps *l*, *l*; *c*, *e* are the high-pressure primary mains. The insulation between the primary and secondary coils is supposed to have broken down at *a*, so that *P* and *S* are in metallic contact with each other through the fault. Now, in an alternating-current system, as installed in the ordinary town or city, there is always more or less of a ground on the primary side of the circuit. This is especially the case in wet weather; hence, we will suppose that a partial ground exists in the primary, as indicated at *e d*. If, under these circumstances, a person in contact with the ground at *f* touches a lamp connection at *b*, the chances are that the shock will prove fatal because he may be subjected to the full primary pressure. In one case known to the writer, a person standing on a damp cellar floor was killed by bringing his hand in contact with a lamp socket. In another case a man was carrying a portable lamp about his room and happened to bring his hand in contact with a stove connected to ground through water pipes, and was instantly killed. It is not known positively in either of these cases whether there was a ground between primary and secondary, but there was evidently a higher pressure than the usual 100 volts on the secondary, and, as there was no direct contact between the primary and secondary wires, it is fair to presume that the transformer insulation was defective. In nearly all cases, the pressures of the primary and secondary of a transformer are widely different, and the whole safety of such systems depends on the thorough insulation of these parts. In modern transformers the insulation is far superior to those made 10 or 15 years ago. Transformers are now subjected to much more rigid factory tests than formerly, and the use of oil immersion has further improved the insulation.

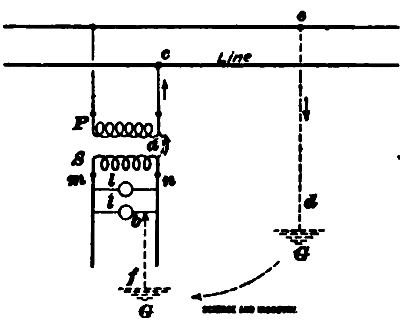


FIG. 1

But there are large numbers of old transformers still in use, especially in the smaller plants, and many of these are by no means safe. They are put up and left up until they burn out, and they are seldom tested to see whether their insulation is good, bad, or indifferent. Anyone who has taken one of these old transformers apart knows about how much the insulation is worth. The long-continued heating reduces the insulation to a powdery state, and the only wonder is that accidents are not more frequent than they are. The worst feature of an impending breakdown between primary and secondary is that there is nothing to give warning that the insulation is

poorer than it should be. No transformer should be put into service that cannot stand a breakdown test between its primary and secondary, with an alternating pressure of at least three times the working primary pressure. The safest plan is to test all transformers at stated periods. This can be done without removing the transformer from the pole. The primary and secondary can be disconnected, and a high alternating-current pressure applied to them by means of a portable testing transformer. A 2,000-volt transformer should stand a 6,000-volt breakdown test, and some manufacturers give them a test of 10,000 volts. Insulation tests with a galvanometer and low-pressure direct current are worthless.

In order to prevent accidents resulting from a cross between primary and secondary, a number of protective devices have been invented. They do not appear to be used very extensively, though they no doubt render the system safer. These devices are intended to automatically ground the secondary in case a breakdown occurs, so that a second ground established by a person will not result fatally.

One arrangement is shown in Fig. 2. Metallic cylinders *c c* are placed between the primary and secondary coils and connected to ground. Since the cylinder covers the secondary, a connection between primary and secondary cannot be established without a connection being made to the shield also. Another grounding device is shown in

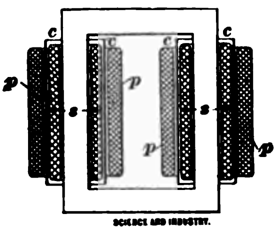


FIG. 2

Fig. 3. A grounded plate *a* is separated from the plates *b*, *b* by a thin film of paper *c*. If the pressure between the secondary and the ground rises to an excessive amount, the paper film is punctured and the secondary permanently grounded. Both these protective devices are due to Prof. Elihu Thomson.

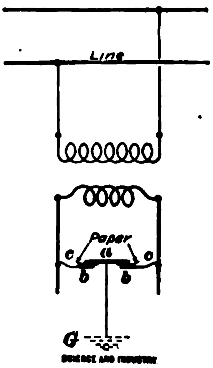


FIG. 3

Fig. 4 illustrates the operation of the Cardew grounding device, which is used considerably in England. The plate *b* is grounded, and attached to it is a piece of thin aluminum foil. If the pressure between the plates rises above 300 or 400 volts, the foil is attracted as indicated by the dotted line, and the secondary thus grounded. These grounding devices are generally installed in duplicate, one on each side of the secondary, so that if one fails to act, the other can take care of the grounding.

The most effective way of overcoming the danger is to ground the secondary permanently. Of course, there are objections to this, because when one part of a circuit is grounded, another ground and consequent short circuit is more liable to develop than if both sides are insulated. The grounding of the secondary is now permitted by the underwriters, although formerly they would not allow it. When the secondary is permanently grounded, the ground connection is usually made at the middle point of the secondary as shown in Fig. 5 (*a*), as this cuts down the pressure, tending to break down the insulation between the secondary wiring and the ground to one-half that of the

transformer secondary. In case the secondary is wound in two sections, as in Fig. 5 (*b*), the ground connection is made between the secondaries. In case transformers are operated on the

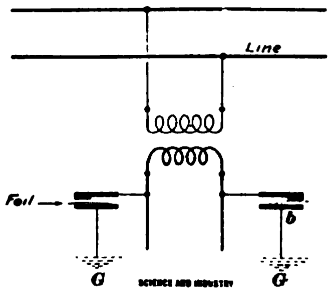


FIG. 4

three-wire system, the neutral wire is grounded. Permanent grounding is a more effective precaution than using grounding devices, and if the secondary wiring is done according to modern standards it should be easily able to withstand the additional strain due to the grounding of the secondary. Earthing devices sometimes fail to work, and at best they do not generally operate until a fault develops.

Although any of the above devices will reduce the danger brought about by defective insulation, the fact remains that by far the greater number of transformers used for supplying light or power to private customers are operated without any precautions being taken to prevent accidents. After all, the vital point is the insulation of the transformer. If the old transformers that have been doing service for years were subjected to a high potential test and the defective ones weeded out, accidents of this kind might not be so frequent. The insulation of a transformer out on the line is bound to deteriorate just as much as the insulation on the alternators in the station. In the latter case the machines are inspected daily and defects are at once noted. In the former the transformer is left to itself and may be in a dangerous state without anybody being any the wiser. Again, a heavy thunder storm may result in damage to the insulation of a number of the transformers. This usually results in a burn-out, and the transformer is taken down and repaired, or the insulation may merely be weakened, in which case the transformer may give out at some future time and become a source of danger.

The transformers should, therefore, be tested systematically by some means or other, so that if the pressure on any of the secondaries rises above its normal value, it will at once be detected. One method that has been suggested is to divide the transformers into groups and run pressure wires to the station from the secondaries of these groups, so that the pressure between them and the ground can be noted. This would be a rather expensive method, but it would indicate the condition of the system at all times. As transformers become older and the number of them in use increases, this danger is bound to increase unless more effective means than are at present used are taken to guard against it. As it is, the deaths

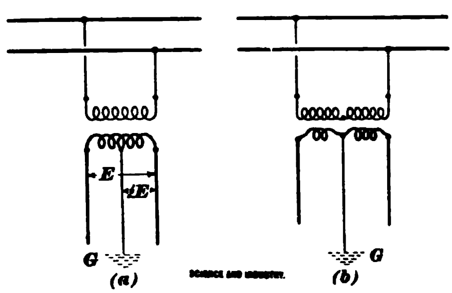


FIG. 5

from this cause are believed by the writer to be more numerous than is generally supposed.

The only sure method of guarding against such accidents is to perma-

nently ground the secondary. As explained above, the grounding of the secondary tends to make other grounds develop in the secondary wiring, but if the wiring is not good enough to stand this, it is high time that the fact should be known. Formerly such grounding was not permitted by the fire underwriters, and there was some excuse for electric light companies not doing it; but now that it is permitted, there is absolutely no excuse for this simple precaution being neglected, and the company that does not do it is taking a large risk. Accidents, where persons are killed by touching a lamp socket while standing on a damp cellar floor, or in any other place where the connection to ground is good, are becoming altogether too common; safety devices are all well enough in their way, but it is a risky thing to stake one's life on a protective device that may or may not work, so it is best to be on the safe side and see that the secondary is well grounded.

MATERIALS OF ENGINEERING

WILLIAM BURLINGHAM

THE materials used in engineering are derived principally from the two bases, pig iron, and copper. These two metals constitute the skeleton frame of our great industries and on the fluctuations in their value depend the business prosperity or depression of our people.

Copper was the first metal used extensively by the human race and many fine examples of the work of our prehistoric forefathers may be seen in the museums today; but that was thousands of years ago and the uses for which copper was then employed have been changed until only the ordinary kitchen utensil can claim a really prehistoric lineage.

The real growth, however, of the mechanical arts, dates from the discovery of the iron ores. This was a large factor in promoting the civilization of humanity.

Iron is the base of the three principal metals used in engineering construction, steel, cast iron, and wrought iron. These three metals are like brothers, insomuch that they are of the same family, yet each has its distinctly individual characteristics.

Steel is the metal that exercises the most potent influence over our manufacturers and the different kinds may be grouped under three heads:

First.—Those steels made of malleable or carbureted wrought iron.

Second.—Those made of cast iron partially decarbonized.

Third.—Those made of highly carbureted iron which is first completely decarbonized and then recarbonized to the proper degree in a single process.

Steels of the first and second classes are made by what are known as the crucible and puddled steel processes, respectively; steel of the third class is made by the Bessemer and Siemens-Martin air-blast processes.

The majority of the steel used today is furnished by the crucible, Bessemer, and Siemens-Martin processes.

Crucible steel is manufactured as follows:

A crucible, composed of clay mixed with a large proportion of graphite is placed on a stand of refractory material above the grate bars of the furnace. These pots are charged with broken blister steel and manganese, with sometimes a flux of glass. They are then

covered with a lid and for an hour or so they are allowed to remain at a temperature of about 3,600° Fahrenheit; at the end of this time, if found to be thoroughly melted, the mixture is poured off or "teemed" as it is termed.

The metals chromium, titanium, and tungsten are introduced when chrome steel, etc., are desired.

The resulting ingot is so sensitive to the carbon introduced that skilled inspectors can tell by the fracture, the amount of carbon in the metal to within five to seven one-hundreths of 1 per cent.

This steel is without doubt superior to any other that is made but because of its high cost of manufacture and the satisfactory substitutes that are offered by the other processes, its use is limited to certain types of work. It must be understood that it would be absurd to use this crucible steel in places where it would outlast the rest of the machine; consequently the inferior metal becomes practically the best for the purposes required.

Crucible steel is used for the following purposes:

All tools requiring a fine cutting edge, such as lathe tools, taps, milling cutters, razors, needles, etc.; for fine dies where sharp outlines and great endurance are required; for fine springs, files, saws, and kindred uses. The steel is divided into 15 or more different tempers, ranging in carbon from .50 to 1.50 per cent.

.50 to .60 per cent. is best for that containing battering tools.

.60 to .70 per cent. carbon is used for hot work, battering tools, and dull-edge tools.

.70 to .80 per cent. carbon is used for battering tools and some forms of reamers and taps.

.80 to .90 per cent. carbon is used for cold sets, hand chisels, drills, taps, reamers, and dies.

.90 to 1.00 per cent. carbon is used for chisels, drills, dies, axes, knives, and similar purposes.

1.00 to 1.10 per cent. carbon is used for axes, hatchets, knives, and large lathe tools.

1.10 to 1.50 per cent. carbon is used for latne tools, graving tools, scribers, scrapers, and small drills.

The best all-around steel is that between .90 and 1.10 carbon.

The Bessemer process of making steel is probably practiced more extensively than any other. It is sometimes called the pneumatic process and consists in the agitation of molten cast iron in the presence of oxygen forced into its mass by jets of air under heavy pressure, producing combustion and removing the carbon. The air streams up through the molten iron in minute bubbles, securing rapid combustion, this combustion being sufficient to supply the needed heat. This process was invented independently by Sir Henry Bessemer, in England, and William Kelley, in the United States.

TABLE A

Ordinary Steel	Tensile Strength	Elastic Limit	Elongation Per Cent.	Contraction Per Cent.
Annealed	58,000	28,000	28	55
Annealed	80,000	87,000	23	45
Oil tempered with axial hole	80,000	45,000	25	50
Nickel steel				
Annealed	80,000	45,000	23	45
Oil tempered with axial hole	80,000	50,000	25	50
Oil tempered with axial hole	90,000	60,000	22	50

At first the lining of the bottle-shaped converter was of silicious or acid material but it was found that all the phosphorus and sulphur remained in the steel, and it became necessary to make sure that there were no more of these objectionable elements in the cast-iron base than were wanted in the steel.

The highest limit for phosphorus is .10 per cent. With too much sulphur the metal becomes red short.

For the European ores, which are high in phosphorus, the basic process was invented; that is, the lining of the converter is made of a material which combines with the phosphorus of the molten cast iron so that the product of the converter is free from all but the slightest traces of that undesirable element.

Because of the freedom of our native ores from phosphorus, the acid process is the most generally used in this country.

By the Siemens-Martin or open-hearth process, the reduction of the metal is obtained by the Siemens regenerative furnace. This process consists, first, of melting a bath of cast iron on a specially prepared sand bottom, then adding wrought iron to the bath until by this addition and the action of the flame, the carbon and the silicon of the cast iron are reduced, and the molten steel results.

The basic open-hearth process is merely the substitution of a bed of dolomite or magnetite for the sand. This removes the phosphorus as in the Bessemer process.

The basic open-hearth process is the method of steel making that furnishes the majority of the steel that is used in our mechanical manufacturing.

For boiler plates, armor plates, and gun parts, the open-hearth steel is beyond present competition.

There are many and various steel alloys; the ordinary one being used for tools, etc., of late years; however, nickel steel is rapidly coming to the front for the making of high-class engine parts and shafting. Nearly all the working parts of the engines built for the vessels of the United States Navy are forged of nickel steel, oil tempered and annealed. The employment of this metal means a gain of many horsepower for the same weight and space occupied by engines built of the ordinary commercial steel.

TABLE B

	Ultimate Tensile Strength	Elastic Limit	Elongation Per Cent.
Rivet steel	48,000 to 58,000	Not less than ½ ultimate	26
Soft steel	52,000 to 62,000	Not less than ½ ultimate	25
Medium	60,000 to 70,000	Not less than ½ ultimate	22
Special open-hearth, extra soft steel	45,000 to 55,000	Not less than ½ ultimate	28
Firebox steel	52,000 to 62,000	Not less than ½ ultimate	26
Flange or boiler	52,000 to 62,000	Not less than ½ ultimate	25

Table A shows the comparison between nickel and ordinary steel.

At the present writing, nickel steel is most extensively used in marine engineering and ship building. It is a metal whose elastic limit is equal to the ultimate strength of ordinary carbon steel, and mild nickel steel has all the properties of high carbon steel without its brittleness.

The standard specifications for steel, adopted by the Association of American Steel Manufacturers, contain the

following requirements: (See Table B.) This steel can be made by either the open-hearth or the Bessemer process.

The Pennsylvania Railroad requires that shell steel plates be rejected if of a tensile strength of less than 55,000 pounds; if the elongation is less than the quotient of 1,400,000 divided by the tensile strength. If the tensile strength is over 65,000, unless the elongation be 28 per cent. or over.

For firebox steel the plates will be rejected if the tensile strength is less than 55,000, if the elongation is less than the quotient of 1,400,000 divided by the tensile strength, and if of a tensile strength of over 65,000 unless the elongation is 30 per cent. or over.

The quotients of 1,400,000 divided by the tensile strength are for 55,000 — 25.4 per cent., 60,000 — 23.3 per cent., 65,000 — 21.5 per cent.

Illinois Steel Company: For flange or boiler steels, maximum limit of phosphorus, .06 per cent.; of sulphur, .04 per cent. For firebox and extra soft steels, .04 per cent. of sulphur. (See Table C.)

The preceding tables give us a very good idea of the ordinary commercial requirements of steel. This steel is the material quoted in the price lists and market reports, but does not at all represent the quality that steel makers can put out if they are required to do so. Below are given the requirements of the United States Navy as a comparison.

The steel used by the navy, and it amounts to thousands of tons a year, passes all the required tests and we have yet to hear of any accident refuting the justness of specifications. The steel is naturally more expensive than the ordinary commercial article, but the saving in weight, especially in marine work, more than counterbalances this loss. The aim of the United States Bureau of Steam Engineering has been to bring the quality of our steel up to an even higher standard, and the first-class quality of our commercial steel today is largely due to the requirements of the United States Government during the past 10 years, compelling manufacturers to increase the quality of their output; consequently the Government requirements are from 3 to 5 years in advance of the commercial requirements. As the steel makers fill the Government specifications, the Government gradually asks for better and better material. The steel listed in Table D is procurable in any first-class steel plant in the United States. For forgings, the physical and chemical requirements are as given in the table.

TABLE C

	Ultimate Strength	Elastic Limit	Elongation Per Cent.
Extra soft steel	45,000 to 55,000	Not less than ½ ultimate	28
Firebox steel	52,000 to 62,000	Not less than ½ ultimate	26
Flange or boiler steel	52,000 to 62,000	Not less than ½ ultimate	25
Soft steel	52,000 to 62,000	Not less than ½ ultimate	25
Medium steel	60,000 to 70,000	Not less than ½ ultimate	22
Rivet steel	48,000 to 58,000	Not less than ½ ultimate	26

All forgings except class C are annealed as a final process. All oil-tempered forgings are bored through axially, if forged solid and more than 5 inches diameter in any part of their length, not including collars, etc., to enable the manufacturers to get the requisite tempering effect. All forgings are required to be free from slags, cracks, blow holes, hard spots, sand, foreign substances, and all other defects affecting their value.

If the forgings are made from the ordinary square, cylindrical, or polygonal ingot, a discard of 30 per cent. from the top and 5 per cent. from the bottom must be made; unless the ingot is bottom cast, when 20 per cent. discard is made from the top and 5 per cent. from the bottom. Test pieces are taken from each length of propeller shafting from special places, also from crank-shafts, etc.

The requirements for blooms and billets are as follows:

(*a*) Nickel steel, which is not to be again forged or worked hot, the same as for the class of forgings for which it is intended.

(*b*) Nickel steel, which is to be again forged, the same as class A forgings, except that an elongation of 24 per cent. in 2 inches will suffice.

(*c*) Carbon steel, which is not to be again forged or worked hot, the same as for class B forgings.

(*d*) Carbon steel, which is to be again forged, the same as for class D forgings, except that an elongation of 24 per cent. in 2 inches will suffice.

Plates must be free from all slag, foreign substances, brittleness, laminations, hard spots, sand or scale marks, scabs, snakes, etc. One longitudinal tensile test piece and one transverse bending test piece is cut from each plate in such places as may be designated by the inspector. The cold bending test pieces may have their corners rounded to a curve, the radius of which is equal to the thickness of the plate.

Boiler plates shall not be sheared closer to the finished dimensions than once the thickness of the plate along each end and one-half the thickness along each side.

Class C is used for all material of that kind which is not essential to the structural strength of boilers and engines; such as air ducts, ash-dumps, ash-pans, ash-pit doors, blower casings and fans, boiler casings, circulating plates, buckets (coal and ash), furnace doors, ladders, oil tanks, smokepipes, up-takes, feed and filter tanks.

TABLE D

Class	Material	Treatment	Minimum Tensile Strength	Minimum Elastic Limit	Minimum Elongation in 2 Inches Per Cent.	Maximum Amount of		Cold Bend About an Inner Diameter of
						P.	S.	
High grade.	Open-hearth nickel steel.	Annealed and oil tempered.	95,000	65,000	21	.06	.04	1 inch through 180 degrees.
Class A	Open-hearth either nickel or carbon steel.	Annealed oil tempering optional.	80,000	50,000	25	.06	.04	1 inch through 180 degrees.
Class B	Open-hearth carbon steel.	Annealed.	60,000	30,000	30	.06	.06	½ inch through 180 degrees.
Class C	Open-hearth or Bessemer.		45,000		20			1 inch through 180 degrees.

Rivets.—Samples from each lot of 500 pounds must withstand the following tests without fracture:

Test (*a*) applied to one lot; test (*b*) to a second, etc.

(*a*) Bend double, cold, to a curve of which the inner diameter is equal to the diameter of the rivet.

(*b*) Bend double, hot, through an angle of 180° flat back.

(*c*) The head to be flattened when

hot without cracking at the edge until its diameter is two and one-half times the diameter of the shank.

(*d*) The shanks of sample rivets to be nicked on one side and bent cold to show the quality of the material.

For bolts and nuts, the material must show a tensile strength of at least 48,000 pounds per square inch and an elongation of at least 25 per cent. in 8 inches.

The preceding requirements show the superior quality of the steel when furnished for government work.

In this work, the class of steel that is most suitable for the work in hand is used; while for ordinary commercial work the same steel is used for nearly everything.

As we advance in our machine design, we must of necessity approach nearer to the requirements of the government work, as this class of work is nearer practical perfection than any other in this country. Naturally, there are abuses in this work as in any other, and many theoretical perfections are called for that are practically impossible to achieve at present, but it is best to have a standard that takes all our skill of manufacturing to approach.

The following lists show the class of material used for a particular part:

High-Grade Machinery Forgings.—Crank, line, thrust, propeller and reversing shafts; piston and connecting rods; crosshead pins, valve stems, links and blocks; eccentric rods with their bolts and nuts.

Class A, No. 1, Machinery Forgings.—Columns, tie-rods, and other engine framing; reversing engine, piston, and connecting rods.

Class B, Machinery Forgings.—Reversing arms, handling gear, and many parts not elsewhere included. All bolts or studs and flanges of steam cylinders or valve chests in steam pipes or water pipes subject to pressure when material is not otherwise specified will be made of class A, No. 1 or No. 2 machinery forgings. Other bolts and studs will be of steel, class B, machinery forgings.

As an example of the increase in the capability of our steel plants to furnish a superior class of steel, the following comparison is offered:

BOILER PLATE—TABLE E

PHYSICAL AND CHEMICAL CHARACTERISTICS OF STEEL BOILER PLATES

Class	Material	Minimum Tensile Strength	Minimum Elastic Limit	Elongation Per Cent. in 8 Inches	Maximum Amount of		Cold Bend About an Inner Diameter
					P.	S.	
Class A	Open-hearth steel.	70,000	37,000	22	.04	.03	Equal to thickness of plate through 180 degrees.
Class B	Open-hearth steel.	60,000	32,000	25	.04	.03	Flat back through 180 degrees.
Class C	Open-hearth or Bessemer.	To be in accordance with the Standard Specifications of the Association of American Steel Manufacturers for structural steel. Revised July, 1896.					

It will be seen that since 1898 the requirement as to tensile strength has been reduced as the percentage of phosphorus has been increased. It was entirely too high for practicability, and, on request of the manufacturers, was reduced. The method of making up these requirements is as follows:

The Government steel experts hold communications with all the principal steel manufacturers, and, as a result, the information thus secured is boiled down into practicable shape, in order to secure the best practical steel. The expense of providing this material

cuts no figure, as all bidders on Government work have the privilege of finding what the price of this class of steel will be.

Under the boiler-plate classification, class A is used for shells, butt-straps, girder plates, stiffening rings, and doubling plates.

Class B, boiler heads and manhole plates, combustion chambers and furnaces.

With this high grade of steel for engines and boiler work, and the necessary factor of safety, it is easily seen that the dimensions of the moving parts of an engine are materially reduced, allowing higher revolutions and better balanced engines.

Some test specimens from one of the latest torpedo-boat line shafts showed a tensile strength of from 110,000 to 113,000 pounds per square inch, and were nearly 7 inches in diameter.

We await with impatience the day when all our steel will approximate those figures.

BOLTS, NUTS, AND RIVETS

Class	Material	Minimum Tensile Strength	Minimum Elastic Limit	Minimum Elongation 8 Inches Per Cent.	Maximum Amount	
					P.	S.
Class A	Open-hearth nickel or carbon steel.	75,000	40,000	23	.04	.03
Class B	Open-hearth carbon steel.	58,000	30,000	28	.04	.03

Cold and quench bend about an inner diameter equal to the thickness of test piece. Quenching temperature 80° to 90° Fahrenheit. Inner diameter equal to ½ the thickness.

The influence of the various elements in steel, generally speaking, is as follows:

Carbon added to pure iron, hardens and strengthens it, while reducing ductility and ultimate resilience; it confers upon steel the property of hardening when suddenly cooled and of regaining its softness by a slow reduction of temperature.

UNITED STATES NAVY BOILERS

Date	Material	Minimum Tensile Strength	Minimum Elongation 8 Inches Per Cent.	Maximum	
				Phosphorus	Sulphur
1892	Boiler-shell plates.	58,000	22	.035	.04
1895	Boiler-shell plates.	65,000	22	.035	.04
1898	Boiler-shell plates.	74,000	21	.035	.03
1901	Boiler-shell plates.	70,000	22	.04	.03

Manganese hardens steel and iron, diminishing its malleability and ductility to a less extent than carbon; it is very effective as a preventive of red-shortness caused by sulphur.

Mushet, an old authority on steel, chronicles this metal as an antidote to sulphur, silicon, and oxygen.

Sulphur causes brittleness at high temperatures, and is especially bad if steel is to be welded; 2 per cent. being the extreme amount allowable in malleable steel.

Silicon, a hardening element. In making ingot steel by the pneumatic process, it is a good fuel for elevating the temperature of the molten mass to a higher point than could be obtained by carbon alone. Mr. R. H. Thurston states that he has found that copper strengthens and toughens steel when added in very small quantities.

The chief bad qualities caused by these impurities are red-shortness, cold-shortness, and hot-shortness.

Steel is red-short when it is brittle at a low red heat, cherry or orange red, caused chiefly by sulphur or oxygen. It must be worked at a high heat or it will crack.

Hot-short steel cannot be worked at a high heat—say above a medium to a bright orange—but works soundly from medium orange down to a dark orange. Hot-shortness is peculiar to steel containing considerable quantities of tungsten, manganese, or silicon.

Cold-short steel is weak and brittle when cold, either hardened or unhardened. Phosphorus is the one element which produces this effect. Cold-short steel must be avoided under any circumstances, unless for making paper weights.

GOOD AND BAD PRACTICE IN STEAM AND WATER FITTING

W. H. WAKEMAN

SEVERAL ILLUSTRATIONS OF WELL-DESIGNED WORK; ALSO OF MISTAKES MADE BY INCOMPETENT MEN—IMPORTANT SUGGESTIONS TO THOSE WHO ARE EMPLOYED TO ERECT AND REPAIR STEAM AND WATER PIPES

IN ONE corner of my boiler room there is a tank 4 feet 3 inches high, and 3 feet in diameter, that appears to be a great mystery to visitors, so that it becomes necessary to frequently explain its use and value. (See Fig. 1.)

The 2-inch blow-off pipe from the boiler discharges into it at the bottom and a $3\frac{1}{2}$-inch horizontal outlet is provided near the top, shown at the left hand.

There is also a 3-inch vertical outlet in the top head. The object and method of operation of the device are as follows: When a boiler is blown down each morning, hot water under pressure enters the tank through the blow-off pipe, and as it is thus released from pressure, some of it flashes into steam, which passes out through the vertical pipe to the outside air. When the tank is nearly full of water it runs out of the $3\frac{1}{2}$-inch pipe to the sewer. If the 2-inch pipe discharged directly into the sewer it would destroy said sewer in that vicinity, as neither cement pipe nor brickwork will last long when hot water under pressure is discharged against them. As the two outlets afford more than 5 times the area of inlet the pressure is much reduced, so that the water flows away without causing a "set back" through other pipes discharging into the same sewer. As some of the water flashes into steam its

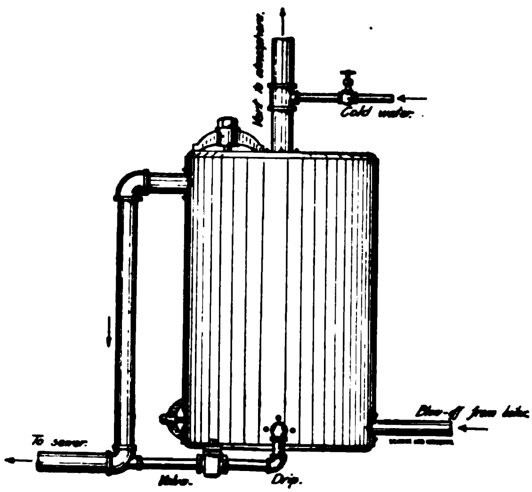


FIG. 1

volume is greatly increased before it rises to the 3-inch vent, so that it is not fair to make a direct comparison between the area of inlet and outlets on this account, but a cold-water pipe is connected to this vent, by means of which the vapor is condensed, and after the blow-off valve on the boiler has been closed, the cold-water valve may be opened wide and the tank full of hot water cooled off. If the 3-inch vent is thrown out of the calculation the $3\frac{1}{2}$-inch outlet is more than three times the area of the inlet, so that the pressure is greatly reduced.

There is a $1\frac{1}{2}$-inch drip pipe near the bottom, so that nearly all of the water can be drawn off. It would be better if it were placed at the very lowest point so that all of the water could be released. There is a handhole in the top head, for the purpose of cleaning the tank.

The section of horizontal pipe shown in Fig. 2 is 2 inches in diameter, and forms part of the feedpipe of a battery of boilers. The vertical outlet is $1\frac{1}{4}$ inches and the remainder is smaller.

It was put in as a safeguard against oil going into the boilers. Water is

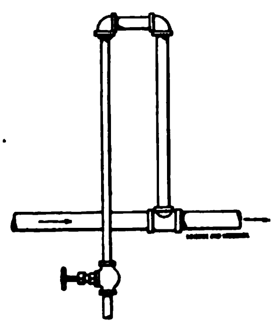


FIG. 2

pumped through this pipe in the direction indicated by the arrows, for a horizontal distance of 16 feet before reaching the vertical outlet, and during this time any oil that may be in the water has an opportunity to rise to the upper part of the pipe, so that when it reaches the stand pipe it can rise into and remain there until blown out through the valve provided for that

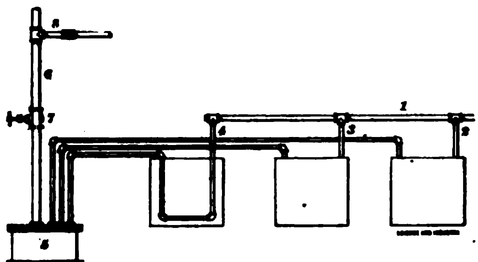


FIG. 3

purpose. An essential feature of the device is that the pipe must be laid horizontally for at least 15 feet before the stand pipe is put in.

Fig. 3 illustrates three small ovens used for heating certain articles in a manufacturing plant. The interior of one at the left is shown, and the others are like it. Live steam enters through *1*, and passes through *2*, *3*, and *4* to the ovens, but there is no outlet for the water which results from the condensation of steam; therefore it must be blown out through the pipes to the trap *5*. The vertical pipe *6* is the main drip pipe from the heating system of a factory five stories high. The valve *7* shown in dotted lines was not put in until the system had been in use for several years. The horizontal pipe *8* is the drip from the first floor, and there is a similar drip on each floor.

Now so long as steam was required to heat the building the trap received all the water of condensation and discharged it into the sewer, and no special fault was found with the arrangement (except the lack of drips already mentioned), but when warm weather rendered steam heat unnecessary, trouble began. Three pipes discharged steam and water into the trap *5*, which allowed the water to run away, but did not

control the steam which backed up the pipe *6*, and thence entered the heating system where it was not wanted.

When complaint was made of this nuisance the superintendent had the

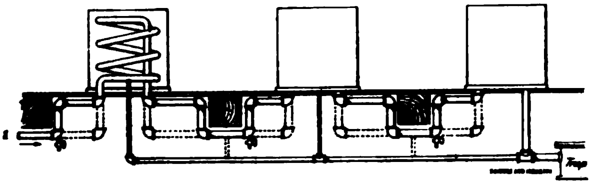


FIG. 4

nipple at *8* taken out, and a plug put in its place. This process was repeated for each floor, which prevented the heating pipes from making the rooms uncomfortable, but did not prevent steam from escaping to the atmosphere through the pipe *6*, which extends through the roof, as the system was calculated for heating by exhaust steam only, which requires a vent. It was necessary to keep a good supply of steam on the pipe *1*, in order to do the required heating, hence a large volume of it was wasted every day.

The engineer advised that a valve be put in, as shown at *7*, so that the vent could be shut off, but was unable to have the improvement made at once,

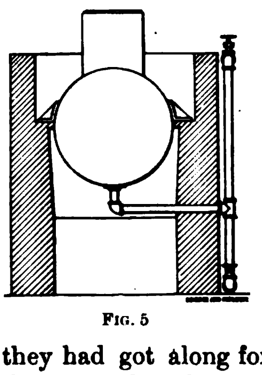


FIG. 5

because they had got along for many years without a valve there, and the proprietor could not see the necessity of putting one in. However it was done finally, and it saved coal enough in less than three days to pay the bill.

Fig. 4 illustrates another case where the piping is improperly arranged and gave poor service accordingly.

Three small ovens were to be heated by steam to a high temperature, so that a coil was required in each. The arrangement is illustrated in one of them, and the others are similar. Steam enters through the pipe at *1* in the direction indicated by the arrow and passes through the first coil, then down around the timber shown, and up into the second; also into the

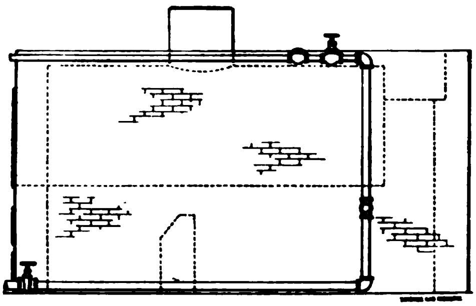


FIG. 6

third in like manner, after which it is run into the drip pipe, and thence into the trap as shown. This plan calls for fifteen ells, where only five are actually required, as shown by the dotted lines. It looks like a job done by the day, by somebody who tried to dispose of as many fittings as possible in a small space.

If that was the only objection it would be a matter of unnecessary first cost only, but in addition to this it now must be charged with poor service and useless labor and care for the engineer, as water collected in the horizontal pipes below the timbers, making it necessary to open the pet cocks about once an hour, or else the required temperature would not be secured in the ovens. If drip pipes were connected

to the main drip, as shown, better service would have been secured with less labor.

Going into an office a short time ago, I found it difficult to carry on a conversation on account of a constant and loud clicking in a radiator. Investigation showed that the drip pipe after leaving the radiator ran "up hill" instead of down, so that it was about 4 inches higher where it joined the main drip, consequently a trap was formed that prevented free passage of the water of condensation, and caused the noise mentioned. If this had been found in some small, out-of-the-way

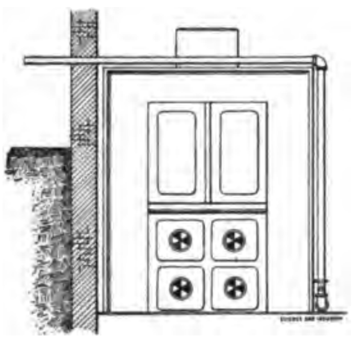


Fig. 7

place, it would not have caused surprise, but it was near the business center of a flourishing city.

After the steam piping in a large addition to a certain manufacturing plant was finished, it was impossible to get steam to circulate through it properly. The usual custom of connecting the main steam pipe to the main drip pipe at short intervals had been followed in this case, as it was considered necessary to do so, to prevent pounding, but when the contractor admitted that he could not make the circulation perfect, the engineer disconnected some of those drip connections and put plugs in their places, after which there was no trouble about getting steam around the room. Before this was done the line was "short circuited," but the new plan made this impossible.

In another place an engineer found

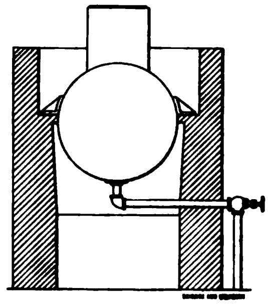


Fig. 8

it impossible to get the cold water resulting from the condensation of steam when first turned on in the morning, back into his boilers, on account of defective arrangement of piping, that could not easily be changed. He put an outlet in the main return pipe near the boilers; then, by shutting the blow-off valves and opening this outlet, the water was quickly forced into the sewer, and after the return pipe was well heated, water flowed back to the boilers without trouble. This wasted some

Fig. 9

cold water, but little heat, because only cold water caused trouble.

Fig. 5 is a rear view of the first

tubular boiler that I had charge of, showing the feed and blow-off pipes combined in one, where they enter the shell. Fig. 6 is a side view of the same. The vertical blow-off pipe was 2 feet long and the horizontal piece 16 feet long. The gate valve used on the blow-off leaked badly, so that a plug was screwed into it. At that time I was not impressed with the importance of opening the blow-off valve on a boiler, every day, and as it was some trouble to use this one, on account of the necessity of removing the plug, screwing in a nipple, followed by an ell and a long piece of pipe to carry the water out of a convenient window, it was not disturbed for several days, and when it was opened wide under 75 pounds pressure, no water appeared, as the long horizontal pipe was full of mud. Sharp blows with a steel hammer loosened it, and the blow-off valve was never kept closed long enough to allow so much sediment to collect again.

In order to make it more convenient for use, a new valve was put on, and the pipe carried up over the shell, as shown in Fig. 7, as the boiler was set low. This did not remove the necessity for blowing off under pressure, which was a bad feature, but the water could not be run out when the boiler was cool, with this arrangement.

Where a tubular boiler is to be fitted with a Jenkins Brothers' valve I would have it arranged as shown in Fig. 8, where an angle valve appears on the blow-off pipe, while the feed enters through the front head and is discharged at the rear.

The full lines in Fig. 9 show a gas pipe as put up by a man who was not familiar with this kind of work. The main supply pipe is 2 inches in diameter, and from this it was desired to carry a ¾-inch pipe to the opposite side of the steps through a brick wall.

As it was not convenient to take down the main pipe, it was not disturbed, but a loop made as shown, in order to bring the pipe below the steps where it would be out of the way. This was undoubtedly the best plan to adopt, on every account but one, which was that the loop thus formed made a place for objectionable matter to collect. It was taken down and replaced, as shown by the dotted lines, although it was then in the way, and was far from being a neat appearing job. While this incident does not relate to either steam or water fitting, it belongs to a closely allied subject, and is introduced here as being of interest to engineers who attend to their own pipe fitting.

COPPER WELDING

PROF. J. R. M'CALL, in the Record of the University of Tennessee, gives the following directions for welding copper: "The copper should be treated with potassium nitrate and a cyanide, after which it is welded to itself, or to iron or steel, in the same way that iron is welded in the ordinary forge shop. A clean fire of coke or charcoal and a temperature of the copper considerably below a white heat insures the best results. A temperature above this makes the metal brittle in working, while one much below will not give sufficient fluidity to the flux. In tension tests the welded joints developed practically the whole strength of the copper."

REVERSAL OF THE DIRECTION OF ROTATION OF A MOTOR

F. H. DOANE

REASONS FOR CHANGE—THEORY—DIAGRAMS OF CONNECTIONS

ONE of the advantages of an electric motor is the ease with which a change in the direction of rotation of the armature of the motor may be made. A motor which has been running in a certain direction is to be installed in a new location, where it is necessary that its direction of rotation be reversed. The reversal in rotation is brought about by a few simple changes of the connections to the field coils, or to the armature. The motor now runs in the opposite direction and the necessity of crossed belts is obviated.

It would perhaps be of interest at this point to see why the motor armature rotation is reversed, when the direction of flow of current in either the field coils or the armature is changed. When a current flows in a wire a magnetic field is set up around the wire. In Fig. 1 the current flows along the conductor *a a*, in the direction indicated by the arrows at the ends of the conductor. The direction of the magnetic whirls set up around the conductor is indicated by the arrows near the top and bottom of the circles. If the direction of the current is reversed, the direction of the magnetic whirls is

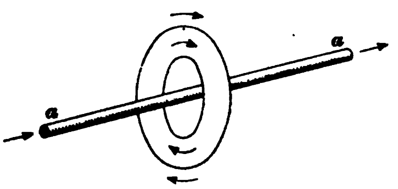


FIG. 1

reversed. The direction of the current and the direction of the resulting magnetic force are related to one another, as are the rotation and the forward travel of an ordinary right-hand screw.

In either a permanent or an electromagnet the lines of force emanate from the north pole, enter the south pole, then pass through the magnet from south pole to north pole. Let us now

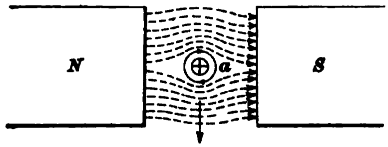


FIG. 2

see what the action is between a conductor carrying current, placed in a magnetic field, and the magnetic field.

In Fig. 2, (*a*) represents a conductor carrying a current which is flowing away from the observer, and *N* and *S* represent the north and south poles of a field magnet. It will be noted that the lines of force of the conductor and the field lines coincide in direction above the conductor and are opposite in direction below the conductor. The dense magnetic field thus formed above the conductor forces the conductor toward the less dense field below it, thus causing the conductor to be moved downwards as indicated by the long arrow. Now, suppose we reverse the current through the conductor, the dense field will now be below the conductor and the less dense field above the conductor; therefore, the conductor is moved upwards toward the top of the page. If we leave the current in the conductor unchanged and reverse the current in the field coils, the polarity of the pole pieces will be reversed and the direction of the lines of force from pole to pole be opposite to that represented in Fig. 2, which will cause the conductor to be forced upwards. Suppose that the direction

of both the current in the field coils and the current in the armature is reversed, the dense field will still be

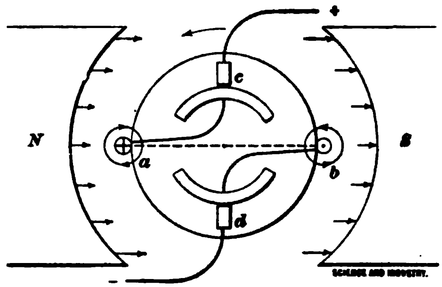


FIG. 3

formed above the conductor and the conductor forced downwards.

Instead of a single conductor let us suppose that we have an armature having one turn of wire wound on its core. One turn will make two active conductors on a drum core. This armature is rotated in a magnetic field. In Fig. 3, brush *c* is the positive brush, brush *d* the negative. Current flows from *c*, through one commutator bar, down conductor *a* and up conductor *b*, through the other commutator bar to negative brush *d*. The interaction of the field lines and the lines set up around the conductors will force conductor *a* downwards and conductor *b* upwards, thus rotating the armature in the direction indicated by

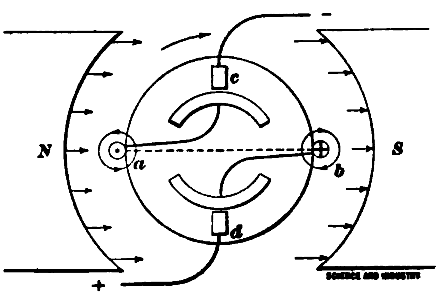


FIG. 4

the arrow drawn over the armature. Suppose we keep the polarity of the pole pieces the same, but reverse the connections of the armature terminals to the + and — line wires. Brush *c* is now the negative brush, as represented in Fig. 4, brush *d* the positive. The current flows down *b* and up *a*. The interaction of the magnetic lines is now such as to force conductor *b* downwards and conductor *a* upwards, resulting in the direction of rotation indicated by the arrow drawn over the armature. It should be noted that this direction of rotation in Fig. 4 is opposite to the direction of rotation in Fig. 3. If we so desired we could have reversed the direction of rotation, by reversing the field-coil terminals, instead of reversing the armature con-

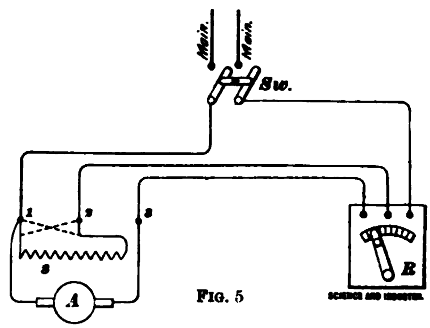


FIG. 5

nections. If we reversed both field and armature connections, we would not change the direction of rotation, as noted in connection with our study of the action of a single conductor in a magnetic field. We thus find that to reverse a direct-current motor the field-coil connections or the connections of the armature terminals must be reversed.

On some motors provided with radial carbon brushes, it is not necessary to alter any of the wire connections to reverse the rotation of the armature, but simply to move the rocker-arm through 180° for a two-pole motor, or 90° for a four-pole motor. The positions of the + and — brushes are thus exchanged, and current flows through

the armature in the opposite direction to the direction of the current before the change was made. If copper or carbon brushes are used that form an angle less than 90° with the commutator, the rocker-arm does not need to be moved through such a large angle, as the brush holders can be so adjusted that the brushes will make contact with the commutator at 180° or 90° from their former contact positions. The brushes should point in the direction of rotation. If it is not convenient to move the rocker-arm, the terminal wires leading to the brush-holder studs may be exchanged. Care should be taken, if this is done on a motor not using radial brushes, that the rocker-arm and brush holders are so adjusted that the brushes point in the direction of rotation. It is often convenient, in a shunt-wound motor, to leave the armature terminals alone and to reverse the shunt field terminals. The connections for a shunt-wound motor are shown in Fig. 5. *Sw* represents the motor switch, *R* the starting rheostat, *A* the armature, *s* the shunt

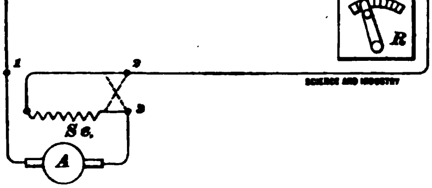


FIG. 6

field. In order to reverse the direction of rotation of *A*, insert the end of *s*, which formerly was connected to motor terminal *1*, into motor terminal *2*. The end of *s*, formerly connected to *2*, should be connected to *1*, as indicated in Fig. 5.

A similar method may be adopted

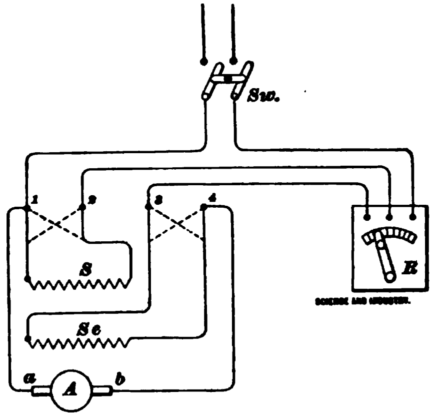


FIG. 7

in reversing a series-wound motor. In Fig. 6, *Se* represents the series field coil. The direction of rotation of the series-motor may be reversed by moving the rocker-arm, exchanging the positions of the leads to the brush-holder studs, or by reversing the connections of the series field leads in terminal posts *2* and *3*.

A compound-wound motor is represented by Fig. 7. If the shunt-field-coil terminals are to be reversed, to cause reversal of rotation, the series-field-coil terminals must also be reversed. If the series-coil or the shunt coil only were reversed, the magnetizing effects of the coils would be such that one coil would tend to demagnetize the other, if they had previously been so connected as to act in unison in building up the field magnetism. If the motor is designed for differentially wound field coils, and only the shunt coil or the series-coil is reversed, the shunt and series-coil will now act in unison in building up the field. To preserve the same relation between the coils, it is necessary to reverse both. It would,

perhaps, be easier to reverse the armature terminals and let the field coils alone. The armature terminals can be reversed by connecting brush (a) to terminal *4*, and brush b to terminal *1*. Reversing the position of the mains at the switch will not reverse the rotation of the motor.

Two-phase alternating-current induction motors may be reversed in direction by reversing the connections to the motor of the two line wires of one of the phases. To reverse a three-phase induction motor, reverse the connections to the motor of any two of the three line wires.

USEFUL FORMULAS—III

JOSEPH E. LEWIS, S. B.

Areas and Volumes

IT IS the writer's purpose in the present article to set down certain facts and data useful in computing areas and volumes. It is well to have some information of this sort committed to memory so as to be able to perform rough computations mentally at any time. It is often very useful to be able to estimate quickly the number of cubic inches of metal in a casting and therefore its weight, or to know how to find roughly the capacity in gallons of a tank without reference to tables, or to figure quickly the heating surface or steam space of a boiler. The ability to do these things often marks the difference between success and failure. One can sometimes produce quite astonishing results by the dexterous use of a little knowledge of this sort.

FIG. 1

It is not a good plan, however, to depend too much on the memory when more reliable sources of information are at hand, and some one has aptly said that the educated man is not he who knows everything, but rather, he who knows how to find out what he wants to know and to use it; nevertheless, one is frequently caught in a position where memory must supply the facts if they are to be used at all, and then the man who has a well-selected fund of knowledge at his command is the one who wins.

For the sake of simplicity we will begin with the area of a rectangle, which is equal to the length multiplied by the width. Bear in mind that the angles of a rectangle are all right angles.

A parallelogram is a figure whose opposite sides are parallel (Fig. 1), but the angles are not necessarily right angles, although they may be, and then the figure is a rectangle. Draw the line A perpendicular to B (Fig. 1). The triangle thus cut off may be placed on the other side, as shown dotted, and we have an equivalent rectangle whose area is A times B. Any parallelogram may be treated in the same way.

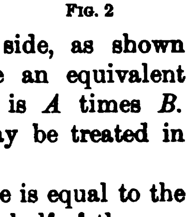


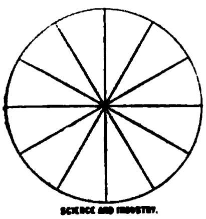
FIG. 2

The area of a triangle is equal to the base multiplied by one-half of the perpendicular height. In Fig. 2 let the base be 3 inches long and the height 4 inches. The dotted lines show how the triangle is cut up, the two small triangles a and b being placed in the positions a' and b', respectively, giving

a rectangle 3 inches long and 2 inches wide, just equivalent in area to the original triangle. Any triangle may be converted in a similar way into a rectangle of equivalent area whose length will always be equal to the base of the triangle and whose width will always equal one-half of its vertical height.

The circle is perhaps the most common area we have to figure in engineering work. Probably every reader can compute the area, but it may be that not all have reasoned the thing out. The area of a circle is equal to the square of the radius multiplied by the quantity 3.1416, usually designated by the sign π; that is, area $= \pi R^2$. Now π is the ratio of the circumference of a circle to its diameter; that is to say, the circumference of a circle is always 3 and a fraction times the diameter, no matter how big or how small the circle. But this fraction cannot be expressed exactly; it is a decimal that may be computed to any number of places but never comes out even. It has been computed to several hundred places for astronomical calculations. The first 15 places are 3.141592653589793; we commonly use 3.1416, and usually $3\frac{1}{7}$ is sufficiently precise for our purpose.

Now it can be readily shown that the area of a circle is equal to the circumference multiplied by one-half of the radius. In Fig. 3 we have divided a circle into triangles. Let us suppose the divisions to be so fine that the base of each triangle is practically a straight line. Now the area of each triangle is equal to its base times one-half of its perpendicular height; that is, its base times one-half of the radius of the circle. The sum of the areas of all the triangles is equal to the sum of the bases, or the circumference of the circle, multiplied by one-half of the radius of the circle. Therefore the area of the circle is equal to the circumference times one-half of the radius; that is,



SCIENCE AND INDUSTRY.

FIG. 3

$$\pi \times 2\,R \times \frac{R}{2} = \pi\,R^2.$$

The area of an ellipse is equal to $\frac{\pi\,A\,B}{4}$ (see Fig. 4). This is similar to the formula for the area of a circle, $\pi\,R^2$, which may be written $\frac{\pi\,D^2}{4}$ or $\frac{\pi\,D\,D}{4}$. The meaning and use of the ellipse formula will be readily understood from its analogy to the formula for the circle.

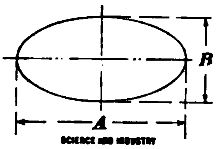


FIG. 4

Take now an irregular figure, as, for instance, an indicator card. The simplest and most accurate way of getting the area is by the use of a planimeter. But every engineer does not have a planimeter, and where this useful instrument is not available the following method may be employed (see Fig. 5). Draw vertical parallel lines about $\frac{1}{8}$ inch apart, as shown. The figure is thus divided into a number of rectangles of the same width but of varying lengths. Find the sum of the lengths of all the rectangles and multiply by $\frac{1}{8}$ inch. This gives a close approximation to the area of the figure.

The area of a cylindrical surface, like that of a boiler, or tube, or pipe, may be calculated from the diameter and length and may be expressed by the formula $\pi\,D\,L$, where D and L are diameter and length respectively.

The area of a conical surface is found by multiplying the circumference of the base by one-half of the slant height. This rule may be readily seen

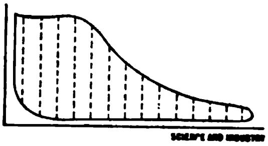


FIG. 5

by developing, or spreading out, the conical surface so that it becomes a portion of a circle (see Fig. 6). The reasoning will now be the same as that used in the case of the circle.

The area of a spherical surface is equal to πD^2, or four times the area of a great circle of the sphere. If one were in doubt as to the exact expression for this, for such things will sometimes become confused in the memory, a pretty close approximation might be had by dividing the area into triangles by drawing meridional lines from the poles to the equator. It will be seen that the length of the equator (or circumference of a great circle) multiplied by the distance from pole to equator (or one-fourth of a great circle) equals very nearly the required area. That is, $\pi D \times \frac{\pi D}{4} = \frac{\pi^2 D^2}{4}$ is very nearly equal to πD^2, it being actually a little smaller, since 3.1416 goes in 4 once and a fraction over. A case like the foregoing shows how reason may often come to the rescue where memory fails.

Turning now to the consideration of volumes, the volume of a rectangular or prismatic solid is equal to the area of the base multiplied by the height, and that of a cylinder is equal to the sectional area times the length. Thus, the number of cubic inches of water standing in a pipe may be computed and from this the number of gallons and the weight of the pipe full of water. Remember that there are 231 cubic inches in a gallon; a gallon of water weighs $8\frac{1}{3}$ lb.; there are $7\frac{1}{2}$ gallons to the cubic foot, and a cubic foot of water weighs about $62\frac{1}{2}$ lb. These figures are only approximate, but are sufficiently accurate for ordinary use.

Diameter Feet	Gallons for 1 Ft. Depth	Diameter Feet	Gallons for 1 Ft. Depth	Diameter Feet	Gallons for 1 Ft. Depth
2′ 0″	23.50	8′ 6″	424.44	15′ 0″	1,321.90
2′ 6″	36.70	9′ 0″	475.87	15′ 6″	1,411.50
3′ 0″	52.86	9′ 6″	553.67	16′ 0″	1,504.00
3′ 6″	71.96	10′ 0″	587.50	16′ 6″	1,599.50
4′ 0″	94.02	10′ 6″	647.78	17′ 0″	1,697.90
4′ 6″	119.00	11′ 0″	710.90	17′ 6″	1,799.20
5′ 0″	146.83	11′ 6″	777.00	18′ 0″	1,903.50
5′ 6″	177.67	12′ 0″	846.40	18′ 6″	2,010.20
6′ 0″	211.44	12′ 6″	917.98	19′ 0″	2,120.90
6′ 6″	248.22	13′ 0″	992.90	20′ 0″	2,350.00
7′ 0″	287.84	13′ 6″	1,070.70	25′ 0″	3,570.70
7′ 6″	330.48	14′ 0″	1,151.50	30′ 0″	5,287.00
8′ 0″	376.00	14′ 6″	1,235.30	40′ 0″	9,367.00

We append the accompanying table for use in computing the capacity in gallons of cylindrical tanks. The first column gives the diameter of the tank in

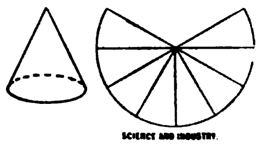


FIG. 6

feet; the second column gives the number of gallons for each foot in length or depth.

To illustrate: the capacity of a 60-

inch tank 10 feet long is 146.83 × 10 = 1,468.3 gal. To find the capacity of any cylindrical tank "off hand," multiply the diameter in feet by itself and by the length in feet and multiply the result by 6. That is, the capacity in gallons equals 6 LD^2 where L and D equal length and diameter respectively. For the 60-inch tank above, the result would be $6 \times 10 \times 5 \times 5 = 1{,}500$ gal., which is a fairly close approximation. It may be noted that the result obtained in this way is about 2% too large and may be corrected accordingly.

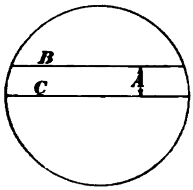


FIG. 7

The volume of a sphere is $\frac{4}{3}\pi R^3$. This formula may be readily remembered from its similarity to the formula for the area of a circle.

From the rules given above one should be able to readily compute the heating surface of a boiler or its capacity in cubic feet or in gallons. Suppose, however, we wish to compute the number of cubic feet of steam space. This involves the area of a segment of a circle (see Fig. 7). The formula for the area of a segment of a circle is complex. But a pretty close approximation may be had by the following method: Compute the area of one-half of the circle. From this subtract the area between the lines B and C. This is approximately $A \times \frac{B + C}{2}$. The area of the segment, then, is $\frac{\pi R^2}{2} - A\frac{B + C}{2}$. This value reduced to square feet and multiplied by the length of the boiler in feet gives the steam space in cubic feet. Suppose, in Fig. 7, the circle is 60 inches in diameter and $A = 10''$; B may be found by measurement or by drawing a circle to scale. In this case it equals 57. The area of the segment, then, is $\frac{\pi \times 30 \times 30}{2} - 10\frac{57 + 60}{2} = 1{,}414 - 585 = 829$. In most cases it would be sufficiently accurate for our purpose if we omit B and compute as follows: Area $= \frac{\pi \times 30 \times 30}{2} - 10 \times 60 = 1{,}414 - 600 = 814$. $814 \div 144 = 5.65$ square feet. This for a boiler 16 feet long gives 90.4 cubic feet of steam space.

In figuring on standard wrought-iron pipe the following table is useful. The first column gives the size of pipe, the second its actual outside diameter, the third its actual inside diameter, the fourth its internal cross-section, the fifth its external cross-section, and the sixth the length per square foot of external surface. All dimensions are in inches except the last column, which is expressed in square feet.

Normal Diameter	Actual External Diameter	Actual Internal Diameter	Internal Area	External Area	Length Per Sq. Ft. External Surface
¾	1.050	0.824	0.533	0.866	3 637
1	1.315	1.048	0.863	1.357	2.903
1¼	1.660	1.380	1.496	2.164	2.301
1½	1.900	1.611	2.038	2.835	2.010
2	1.375	2.067	3.355	4.430	1.611
2½	2.875	2.468	4.783	6.491	1.328
3	3.500	3.067	7.388	9.621	1.091
3½	4.000	3.548	9.887	12.566	0.955
4	4.500	4.026	12.73	15.904	0.849
5	5.567	5.045	19.99	24.30	0.629
6	6.625	6.065	28.89	34.47	0.577

In computing weights it is convenient to carry in mind that a cubic foot of wrought iron weighs 480 pounds. A square foot of wrought iron 1 inch thick weighs 40 pounds.

A cubic foot of cast iron weighs 450 pounds, a cubic inch about one-quarter of a pound. The weight of an iron casting is roughly about 18 times the weight of a pine pattern where there is no core work; for brass the weight is about 20 times that of the pattern.

In computing areas and volumes it should be remembered that absolute accuracy is impossible, and that it is a waste of time to try for greater precision than the case requires. For instance, if it will serve our purpose to know that a tank holds about 1,500 gallons, it is useless to spend time in finding out that the exact capacity is very nearly 1,496½ gallons. One should never measure to sixty-fourths of an inch when sixteenths are sufficiently precise for the case in hand, and conversely it is fatal to stop with sixty-fourths when the case in hand requires an accuracy of one-thousandth of an inch.

PRESSURE TANK FOR CYLINDER OIL

THE pressure tank method of cylinder lubrication is employed in many large steam plants where the use of the ordinary small lubricators would be inconvenient owing to the number required and the amount of attendance that would be necessary to keep them in operation.

The general arrangement of the apparatus used in this system is shown in Fig. 1. The pressure tank *T* commonly constructed of steel should be made amply strong to sustain the maximum pressure required to do the work and of sufficient capacity to hold a barrel of cylinder oil. The top of this tank is connected by a pipe with the sight feed-device *L*, shown in detail in Fig. 3, at the engine. Branches may be taken off this pipe to supply other parts of the plant. From the bottom of the tank a pipe leads to the main steam line, or in some cases to the boiler. In order to force the oil into the steam pipe or other parts of the engine requiring lubrication, against the steam pressure, it is evident that a pressure must be applied to the tank which shall be enough in excess of the steam pressure, at the point where it is desired to introduce the lubricant, to provide for overcoming the resistance of the piping and throttling of valves in the sight feed-devices which regulate the feeding, and also to raise the oil to the required height, in case the tank is below the part of the machine which it is desired to lubricate; the practice being in most cases to locate the tank in the basement or boiler room, as it is more out of the way, and any leakage or spilling of oil is not so liable to cause damage.

There are several methods of obtaining this extra pressure, which should amount to from 4 to 10 pounds per square inch, depending on the length and size of piping, the number of outlets, etc. If the main steam pipe is high enough above the engine a small pipe may be connected to it and led directly to the bottom of the tank, no part of the pipe being higher than the main steam line. The condensed steam will soon fill this pipe, shown by dotted lines on Fig. 1, and the steam pressure plus the pressure of this column of water will force the oil through the oil pipe, which runs from the top of the tank to the sight feed *L* at the engine. The unbalanced pressure available for overcoming the resistances and forcing the oil in against the steam pressure is approximately that due to the column of water *a b*, Fig. 1. If

the steam pipe is not high enough to give a satisfactory pressure the pipe should be carried to a height which will give the desired pressure and then turned downward and connected with the bottom of the tank as before; such a pipe is shown by full lines in Fig. 1. The amount of pressure secured by running the pipe to different heights is shown on the figure. If it is necessary to extend the pipe to a considerable distance either horizontally, vertically, or both, it is important that the section of pipe from the steam connection to the summit, should be so constructed that it will drain readily back to the steam main or boiler; if this is neglected the condensation will be likely to collect in the pipe, which is in effect a siphon, and will tend to counterbalance

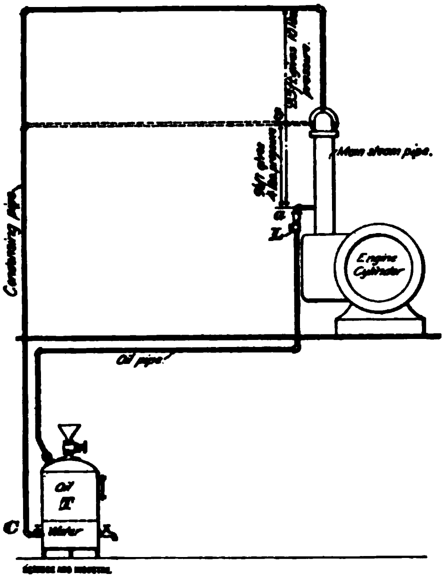


FIG. 1

the column of water in the part of the pipe running down to the tank, thus reducing the pressure and stopping the flow through the lubricators. This method of piping is somewhat similar to the single-pipe system of steam-heating plants where the condensation is returned through the steam supply pipe, and the proper size of return pipe may be determined by the rules which are used for figuring heating pipes. It is a good plan to cover the return pipe from the summit, if it is of considerable length, thus avoiding a large part of

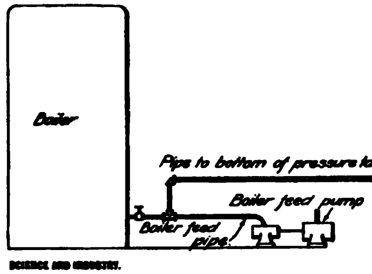


FIG. 2

the condensation and preventing the heating effect which might be unpleasant in warm weather.

Another method of getting the desired pressure consists in running a pipe from the boiler feed-line to the bottom of the tank, as shown in Fig. 2. The connection should be made between the boiler feed-pump and a valve on the feed-line at the boiler. In order to get the extra pressure required above the boiler pressure, this valve must be throttled until the desired pressure is obtained. The chief disadvantage of this plan is that all the water used by the boiler must be pumped against this extra pressure, and any change in the rate of feeding must be provided for by adjusting the valve, which is often inconvenient and is also liable to be forgotten. If a source of water supply having a sufficient pressure is available, it is simply necessary to connect this to the tank, but this method will rarely be found available in large modern plants, as the steam pressure carried is almost always much higher than any ordinary pressure on a waterworks system.

The pressure tank may also be used in connection with any of the mechan-

ical cylinder lubricators, which are quite extensively used and give general satisfaction, owing to the better distribution of the lubricant and closer

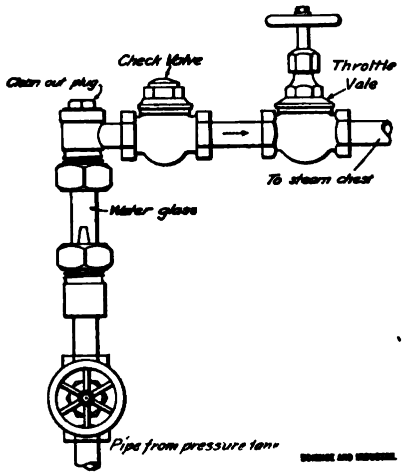


FIG. 3

regulation of the rate of flow. These devices commonly consist of a small reservoir or oil cup provided with a small plunger oil pump which is operated by a connection with some moving part of the engine. The oil pipe from the tank is connected to the oil cup of the lubricator, and the oil may either flow to the pump by gravity, if the tank is above the pump, or be raised by the suction of the pump, if the lift is small and the pump suited to the work, or forced to flow to the required point by any of the methods previously mentioned. As the pump forces the oil in against the resistance of the steam, a very moderate pressure is all that is necessary in most cases to raise the oil from the tank to the lubricator and a connection with the water supply pipe will furnish the required pressure.

In order to provide against interruption to the oil supply, due to filling the tank or repairs to any part of the system, ordinary cylinder oil cups are sometimes put in, connected in the usual way, the oil pipe from the tank being connected to these cups and the lubricant flowing through them into the steam pipe or steam chest. By a proper arrangement of valves they may be cut off from the tank supply and used independently. A hand oil pump is commonly provided, which may be used when the other devices are unavailable.

For convenience in filling the tank, a tackle block or chain fall may be rigged so as to hoist the barrel above the top of the tank. A valve should be connected to the bung hole of the barrel to regulate the flow, and a large copper funnel fitted to screw into the inlet to the tank. If the water is drained out of the tank by a bottom valve as the oil is poured in at the top, the oil will be drawn in to take the place of the escaping water. Where two or more tanks are in use an overhead track provided with a trolley carrying

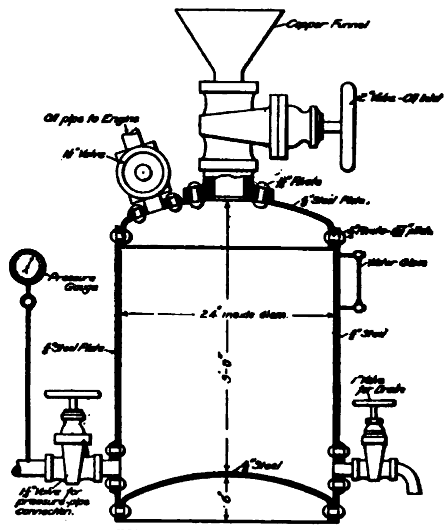


FIG. 4

the chain blocks is a very convenient arrangement.

The tank may also be filled without lifting the barrel by forcing the con-

tents over by means of water pressure applied through a connection made to the lower part of the barrel head, the oil flowing through a pipe or hose connected to the bung hole. Compressed air may also be used for this purpose, but in this case the oil connection would be at the bottom and the air at the top.

The pressure tank may also be used in connection with a distributing pipe to convey machine oil to taps located in different parts of the plant, where the oil may be drawn into measures and used to fill the lubricators. Fig. 4 is a detail drawing of the tank, showing the general dimensions, thickness of plates, connections, etc.

A NEW WAY TO SEND TELEGRAMS

AS REGARDS telegraphy, the present limits are temporarily set; in order to make a marked improvement it would seem that radical innovations will be necessary. It is, however, possible and practicable to make the telegraph carry more communication than it now does, and the mail less. In a certain sense it may be said that at the present time the telegraph carries as much of the mail service as the telegraph rates justify. Consequently, we cannot expect telegrams to rob the mails further unless the cost of telegraphy is further reduced, and it is difficult to see how that cost can be substantially reduced under existing conditions. One way in which the cost of telegraphic transmission can be reduced is by stenographers learning the Morse code, and learning to write out their important letters in perforation upon a band of paper. This band of perforated paper could then be carried to the nearest telegraph office, say in New York, and passed through a mechanical transmitter there at the rate of 1,000 words a minute, for a distance of 1,000 miles, or say to Chicago. The paper band at Chicago, with this message written on it by the automatic action of the receiving instrument, could then be sent by messenger to the Chicago mercantile office of destination, by which process a letter of 500 words would occupy the wire only half a minute. The work of deciphering at the receiving end, and of perforating at the transmitting end, would be accomplished by the stenographers in the receiving and the sending mercantile offices respectively. It is by some such system that we may expect letters which would take twenty-four hours to deliver by express train to take one hour by wire, viz., fifteen minutes in perforation, ten minutes in messenger delivery, ten minutes' delay in waiting turn on the circuit, half a minute in transmission by wire, ten minutes in manual delivery, and fifteen minutes in deciphering, or one hour in all for a 500-word communication.

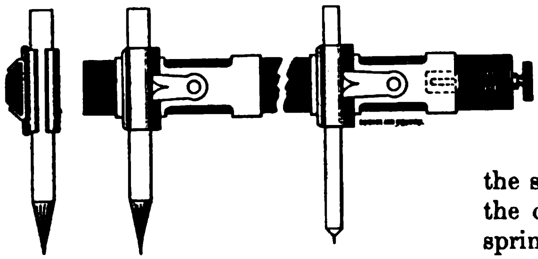
Since hearing by wire is already an accomplished fact in telephony, the question arises as to whether it is possible to see by wire. Seeing by wire appears far more difficult than hearing, since the vibrations of light are counted in trillions each second, whereas those of sound in hearing are only in hundreds; but, after all, the problem is not more unsolvable today than that of hearing by wire must have seemed fifty years ago, and if the presentation to the eye of a distant picture is not accomplished directly, the future may find a means for accomplishing it indirectly.—Arthur E. Kennelly, D. Sc., in the Saturday Evening Post.

USEFUL IDEAS

A HOME-MADE BEAM COMPASS

Thomas C. Harris

Every draftsman feels, at times, the need of a good beam compass, but every draftsman does not possess one. As a good instrument costs anywhere from five to twelve dollars, many of us are obliged to make use of some sort of a substitute or an improvised affair. The accompanying figure shows how a good instrument may be made by the draftsman himself at the cost of a few cents. It is capable of the finest adjustment and



will do work equal to that of the most expensive kind. The beam is a strip of fine-grained hardwood, say 1 inch wide and $\frac{1}{4}$ of an inch thick. Its length may be 18 inches or longer, if required. It should be beveled, as shown, and planed true and straight, the same width the entire length.

The two sides, which are both alike, are made of sheet brass, about $\frac{1}{16}$th of an inch thick, and each has secured to it a spring clip, such as are commonly sold at the stationer's store for holding bills and papers. One of the handles of the spring clip is riveted to the slide, while the jaw, next to the slide, is held by a projection of the slide, which is bent over at each end and clinched down inside the jaw.

There are four ear pieces, one at each corner of the plate, which are bent over to grasp the bevel of the beam, holding it firmly, but not too tightly, to be moved along the bar.

The spring clip will hold a pencil or ruling pen of any size, at right angles to the bar, as shown. The slide on the right-hand side has a lug or ear piece bent down at a right angle, into a slot cut through the wooden bar. This ear piece may be threaded to fit a slim machine screw passing endwise into the slot, or it may carry a nut behind it in the slot, to move the slide when the knob is turned. A stiff spiral spring about 1 inch long and $\frac{1}{4}$ inch in diameter fills the slot and surrounds the screw.

Turning the knob to the right compresses the spring and moves the slide in that direction. If turned the other way, the expansion of the spring moves the slide. In this way the finest adjustment may be made.

Side views of both slides and one end view are shown, making the construction easily understood.

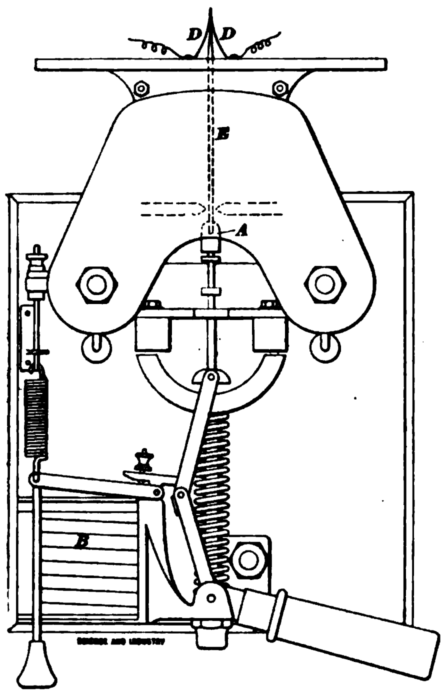
As all the materials for such an instrument may be obtained almost anywhere, no draftsman needs to get along without a beam compass.

PROTECTION AGAINST OPEN CIRCUIT

P. E. Mitchell

The circuit breakers we used were of the General Electric make. At the top of the vertical rod which by moving up or down closes or opens the circuit, there is a small copper block *A* held in place by a screw. The copper blocks all being interchangeable I started on the breaker of the lightest-load circuit, and the one least likely to come out, putting a small wedge on top

of the series magnet *B* to prevent its coming out while I worked on it, and while the copper block was removed. A $\frac{3}{8}''$ hole $1''$ deep was drilled in the top of the block, which hole was tinned



and then filled with solder. I then drilled in the solder a $\frac{3}{16}''$ hole and tapped it with a $\frac{1}{4}''$ standard-bolt tap. During the entire drilling and tapping of the blocks the breaker first started on was left with the wedge in it. When one block was finished I went to the second breaker, put a wedge in it, removed its block and replaced it with the finished block. In that way and without much trouble I went down the line of ten breakers getting them all ready for the signal. I next made two small spring contacts, as at *D*, for each breaker. They were of No. 20 spring brass about $3''$ long by $\frac{3}{4}''$ wide at the widest part. At one end the edge was bent to an angle for the distance of $1\frac{1}{2}''$ and two $\frac{3}{16}''$ holes drilled in the bent part to fasten it to the top piece of the breaker. The screw on each piece nearest the back of the breaker formed the binding-posts of the signal wire. The last thing to complete the signal was the $\frac{1}{4}''$ round fiber rods. The rod *E* is $\frac{1}{4}''$ fiber about $7''$ long. At one end a thread is cut $\frac{3}{4}''$ long, and at the other end it is flattened for about $\frac{3}{4}''$ forming a wedge. The operation of the signal is as follows: When the breaker flies open the fiber wedge is withdrawn from between the contacts, and the signal circuit is closed; and when the breaker is put in the wedge rises between the contacts, opening the signal circuit. Care must be taken that the signal rod is long enough so that it does not entirely leave between the contacts at any time. Only the top part of the contacts need touch to give the signal, and when the breaker is in the fiber will extend about $\frac{1}{4}''$ above the brass.

WIRING TWO ELECTRIC BELLS

A very simple solution, which we give in Fig. 1, to a question asked and differently answered in the October, 1901, SCIENCE AND INDUSTRY, has been sent to us by Mr. James B. Dillon, of Louisville. The question is: how to wire two electric bells, two blocks apart, using only two wires, so that

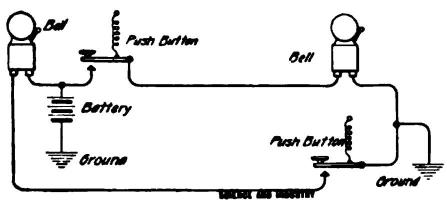


FIG. 1

pushing the button at one end will ring only the bell at the other end. Two ordinary push buttons and only one battery are required in Mr.

Dillon's diagram of connections, which is shown in Fig. 1. If one button is pressed, only the bell at the opposite end will ring, but if both buttons are pressed at the same instant then both bells will ring. This arrange-

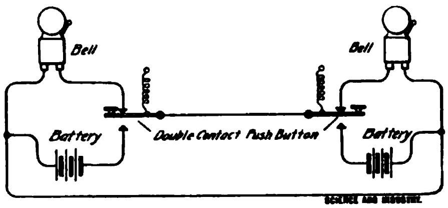


FIG. 2

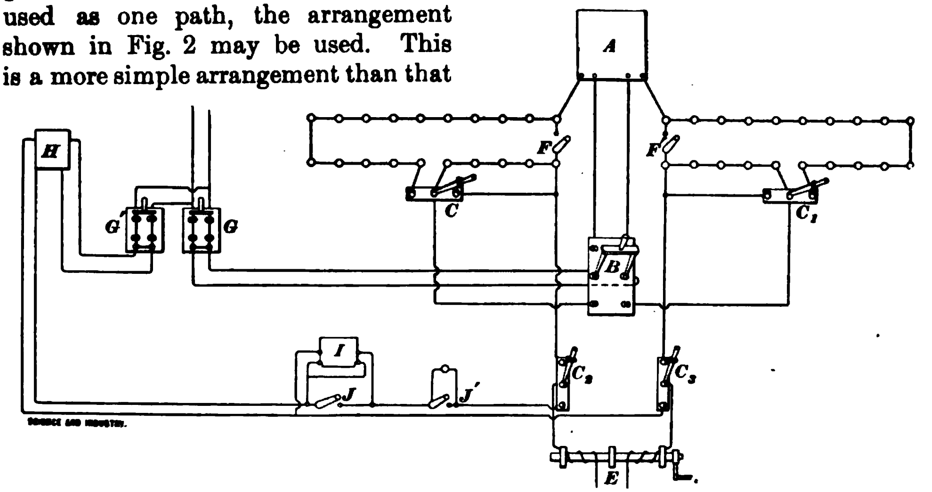
ment makes use of the ground as one path or circuit in addition to the two line wires. In our answer to this question (No. 364) only the two line wires were used as requested in the question, because we had in mind, perhaps without sufficient reason, however, a circuit such as a metallic telephone circuit, upon which it might not be desirable to have any connection with the ground. If the earth must not be used as one path, the arrangement shown in Fig. 2 may be used. This is a more simple arrangement than that given in our original answer to this question. In this arrangement two double-contact push buttons and two batteries are required, and furthermore, if both pushes should be pressed at the same instant, neither bell would ring.

A TESTING SWITCHBOARD

O. B. Eve

The accompanying figure illustrates a switchboard designed for testing the insulation of armatures, transformers, etc.

A is a 1,000 to 4,000-volt transformer, *B* a double-pole double-throw switch, C, C_1, C_2, C_3 are double-pole single-throw switches, *E* reels and testing cables, *F* and *F'* single switches, *G* and *G'* main switches, *H* a 1,000 to 100-volt transformer, and *I* is a tap and switch for wattmeter ammeter and voltmeter for testing transformers for core losses, etc. By means of the apparatus quite a number of changes can be made in both voltage and current. In order to get 4,000 volts through the lamps throw the switches C and C_1 out and C_2, C_3, and *B* up. To get 4,000 volts direct close *F* and *F'*. To get 1,000 volts through the lamps open the switches C and C_1 and throw *B* down. For 1,000 volts direct throw in the switches C and C_1. To get 100 volts through the lamps throw the switches C_2 and C_3 down keeping *J* closed. For 100 volts direct close *J'*. There is a ring and brush on the reels not shown in the sketch.



EDITORIAL COMMENT

A FLYWHEEL ACCIDENT

A 30-foot flywheel on an engine belonging to the Scranton Traction Co., Scranton, Pa., burst on February 21, doing considerable damage.

The engine had been moved out of the power house to make room for a new and larger one being installed there, and was temporarily installed in the car shed from where it operated, by means of a belt, a dynamo located in the power house. The flywheel was of rather unusual construction, the hub, arms, and rim all being cast separately. The arms were hollow and oval in section, being flanged at both ends. They were bolted to the hub, and the rim in sections was bolted to the arms.

Every one of the arms was broken, some of them breaking off close to the rim while others broke off close to the hub. The rim flew apart in a large number of small pieces, some of them going through the roof and landing several hundred feet away. Several cars standing in the shed were struck by flying pieces and completely demolished.

The only person injured was the engineer, whose arm was broken by being struck while trying to shut off the steam.

We are advised that the following scholarships at Lehigh University will be open to competition at the annual examinations in June, 1902.

Two in the Classical Course of $150 and $100 each. One in the Latin-Scientific Course of $125. Five in the following courses: Civil Engineering, Mechanical Engineering, Electrical Engineering, Mining Engineering and Metallurgy, and Chemistry of $150 each.

The above sums will be paid to the successful competitors in two installments during the Freshman year, and the scholarships will be renewed from year to year provided the holders thereof are in full standing in all their studies. All fees are remitted to those holding these scholarships except the fees and deposits required in the various laboratories.

The scholarships will be awarded to the students having the highest general averages in all subjects required for entrance to the above courses, provided, however, that the applicant does not receive in any subject a mark below 70 per cent. Competitors for these scholarships must announce definitely, at least one week before the time of the June examinations (19th, 20th, and 21st), their intention of entering the competition and the course they desire to take. As there is but one prize to be awarded in the departments of Mining and Metallurgy, the successful competitor may choose one or other of these courses.

The examinations must be taken at the University in South Bethlehem. Applications to have the examinations held in other cities will be considered in case there are a sufficient number of students to justify the expense of sending out an officer of the University to conduct them.

There are also a considerable number of scholarships for free tuition in the Classical and Latin-Scientific Courses.

Scholarships through the postponement of payment of tuition are granted to worthy and needy students who give satisfactory evidence of their total inability to pay tuition while in the University, provided they pass all their entrance examinations creditably and maintain good scholarship throughout their college course.

All correspondence with reference to these scholarships should be addressed to N. M. Emery, Registrar.

BOOK NOTICES AND CATALOGUES

THE SCIENTIFIC AMERICAN CYCLOPEDIA OF RECEIPTS, NOTES, AND QUERIES, published by Munn & Co., New York City. Price $5.00.

This book was first published in 1891 and is now in its sixteenth edition. It consists of a compilation of the most useful receipts, and information germane to the scope of the book, which have appeared in the Scientific American for the past fifty years. There are something over 15,000 formulas presented, covering a wide range of subjects, as well as numerous tables of weights and measures and a dictionary of chemical synonyms. As a book for general reference it will be found very useful.

HANDBOOK ON ENGINEERING by Henry C. Tulley. Published by Henry C. Tulley & Co., St. Louis, Mo. Price $3.50.

This book, as the sub-title indicates, is a practical treatise on the care and management of dynamos, motors, boilers, engines, pumps, inspirators and injectors, refrigerating machinery, hydraulic elevators, electric elevators, air compressors, rope transmission, and all branches of steam engineering. Persons desiring information in regard to the theory of engineering matters, or desiring to make an exhaustive study of some particular branch can find plenty of books suitable to their purpose, but a handbook is intended for reference and should consequently contain information on questions which are liable to come up in every-day work. This Mr. Tulley's book unquestionably does and we take pleasure in recommending it to our readers.

The Edward P. Remington Newspaper Advertising Agency, of Pittsburg, Pa., can again take credit for being ahead of their competitors. As in 1901, they are first in the field with their annual Newspaper Directory.

We have before us the 1902 edition, and, as heretofore, we find accuracy and careful compilation of newspaper statistics and values, specially arranged in a concise form for ready reference. This directory is indispensable to the man who wants to know quickly and surely about any newspaper or periodical published in the United States and Canada.

The book contains full and complete lists of all newspapers and other periodicals published in the United States and Canada, with their days of issue, politics, and circulation, and specially classified lists of the principal dailies and weeklies, and the best agricultural, religious, scientific, and trade publications, and leading magazines. All the lists are catalogued by towns in alphabetical order, thus enabling the reader to turn readily to any source of information he seeks and finds just what he wants in the most compact and available form. In the general list the population is given of each state, town, and of the county in which it is located.

We are in receipt of Catalogue F of the Sims Co., Erie, Pa. This concern manufactures a complete line of mechanical boiler cleaners, feedwater heaters, steam separators, exhaust heads, low-water alarms, kerosene-oil injectors, flue scrapers, oil filters, crankpin oil cups, flue blowers, etc. The catalogue is neatly gotten up, and contains descriptions, illustrations, prices, etc., of the articles manufactured by them.

TRADE NOTES

We are advised by Edw. M. Zacharias, 447 Halsey street, Brooklyn, N. Y., that poor and inaccurate drawings can generally be attributed to loose and wrinkled paper on which the drawings are executed. Drawing paper is very sensitive to atmospheric conditions, and when a sheet of such paper is fastened on the drawing board by means of thumbtacks, it may be very smooth at first, but, after being on the board only a short time it becomes loose and wrinkled; the cause of this is the expansion and contraction of the paper, owing to its absorption of moisture from the atmosphere and even the hands, which causes the buckling of the paper, and when dry causes the elongating of the original holes made by the tacks.

The Gem drawing board is especially designed to overcome this defect, being equipped with two clamping stripe fitted into recesses cut into the board, running the entire width of the paper, and held securely by means of thumbscrews from the underside of the board, it not only clamps the paper very securely, but stretches it so

that the ordinary amount of moisture does not affect the stretch of the paper, but always holds it perfectly tight on the board, thus making a hard, smooth surface to draw on.

Gem drawing boards are of the best workmanship; they are made up of narrow strips of thoroughly seasoned wood, with hardwood ledges attached by screws sunk in slots bushed with metal to allow expansion or contraction. The clamping strips are also hardwood, and the nuts used for the clamping of the strips are left open on top to allow the attachment of other instruments.

The L. S. Starrett Co., of Athol, Mass., have rented the beautiful salesroom at the corner of Greenwich and Liberty streets, New York City, and will move their offices there on May 1. The building is known as the "Liberty Building," and Nos. 123 and 125 Liberty St. They will here have all the room and light needed to exhibit their large line of fine mechanical tools. Their new catalogue, showing some fifty new tools, will be ready for mailing about June 1, and will be sent upon application.

The Armstrong Bros. Tool Co. have sent us the following descriptions of tools manufactured by them. Their patent clamp-lathe dog is so constructed as to combine the convenient features of the clamp dog with the simplicity and strength of the ordinary lathe dog. It will accommodate itself readily to work of any shape and will hold it securely and squarely, being especially adapted for use on finished work which would be liable to be damaged by the set screw of a common lathe dog. The sliding block is drawn up to the work by a loose fitting U bolt of steel, threaded on the ends and with case-hardened nuts, loosely fitted, so that they can be run rapidly to size without using a wrench until tightened. The body of dog is cast of steel, and the design is such that there are no projecting screws or other parts liable to catch the file, or the workman's hand or clothing. One advantage of this dog is that it can be adjusted without removing work from centers. It possesses a wide range of adjustment, the seven sizes in which it is made being properly proportioned and balanced to take work from ¼ inch up to 5 inches in diameter.

Their planer jacks are designed to displace the haphazard devices and methods now generally in use for leveling work on machine tools, and a glance will show any mechanic their convenience and utility. A set of these jacks on a machine will greatly reduce the proportion of time required for preliminary arrangements as compared with the actual machine time on the job, and will, moreover, by their perfect adjustability and solidity, insure good, true-surfaced work. The base is substantially made of malleable iron, faced true on the bottom; it is of strong design, an important feature being a split hub and screw (case hardened), providing a convenient means for locking jack-screw in position and of compensating for wear of screw and socket. The tilting cap is of malleable iron, faced on the top, and is attached to head of screw by ball and socket arrangement, which allows it to adapt itself to uneven, irregular, or angular surfaces. The screw is made of steel with United States standard thread, and has hexagon neck for wrench. The jacks are made in four sizes.

The Seneca Falls Manufacturing Co., 94 Water street, Seneca Falls, N. Y., have added to their extensive assortment of wood-working machinery a new size of their "Union" combination saws, known as No. 8. It is designed to supply the demand for a light-power machine for use by carpenters, builders, cabinetmakers, and wood workers generally, suitable for ripping up to 3½ inches; also cross-cutting, mitering, and with attachments, scroll sawing, edge moulding, beading, grooving, dadoing, etc.

It is made with a strong and rigid iron frame, steel arbor, and babbitt-lined boxes, which are adjustable. The combination wood and iron table top is 28 inches wide by 36 inches long; the middle portion of iron is 10×36 inches in area and has in the center two hardwood strips fitted one on each side of the saw. The table is hinged at the back, and can be adjusted up or down by the hand screw in front for rabbetting, grooving, dadoing, etc.

The pulley on outer end of saw-arbor shaft is 3 inches in diameter, 2½-inch face.

The regular "Union" scroll-sawing and "Union" moulding attachment can be used on this machine, and either can be attached almost as easily and quickly as changing saws.

For a more complete description, address the company for their catalogue "A," which also describes their complete line of wood-working machinery.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

MECHANICAL

(84) (*a*) How many revolutions does the governor shaft of a Putnam engine make to one revolution of the crank-shaft? (*b*) How do you equalize the cut-off on a Putnam engine? (*c*) Do all engines use steam full stroke when starting up? (*d*) What makes a check-valve click? (*e*) When running a 125-horsepower engine with a very light load, the steam pressure having been reduced from 85 pounds to 55 pounds, is it better to run with throttle wide open or partly closed?

C. B., Boston, Mass.

Ans.—(*a*) It is not quite clear whether you mean the governor spindle or the cam shaft, from which the governor is driven, by the term "governor shaft." The cam shaft makes ½ a revolution for each revolution of the engine, and drives the governor by bevel gears. To find the number of revolutions of the governor to one revolution of the crank-shaft, count the number of teeth in the bevel gears. Divide the number of teeth in the gear on the cam shaft by the number of teeth in the gear on the governor spindle, and multiply the quotient by ½. (*b*) By shifting the cams on the cam shaft. (*c*) No; generally speaking, only releasing-gear engines take steam full stroke in starting. (*d*) A temporary reduction in pressure on the intake side of the valve causes the pressure on the delivery side to seat the valve suddenly, thus producing a click. This is especially noticeable with single-acting feed pumps. (*e*) Generally speaking, it is better to run with the throttle wide open and cut-off as early as possible. With very early cut-offs, however, it is occasionally found better to run with the throttle partially closed in order to wiredraw the steam and thus superheat it, by its free expansion, to an extent sufficient to partially prevent cylinder condensation. Which plan is the best for a particular case can only be discovered by an actual trial, keeping tally of the coal burned per indicated horsepower per hour.

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(85) How many cubic feet of steam at 100 pounds pressure will be required to heat 600 pounds of water from 100° to 212°? The steam pressure at the exhaust of the circulating pump is 100 pounds; the distance from the pump to the heater is 15 feet, and the pipe is well covered; the feedwater circulates through a system of small pipes enclosed in a steam-tight chamber, the heating surface being 2,600 square inches; the exhaust steam from the pump passes into the chamber containing the pipes. W. H. M. S., San Francisco, Cal.

Ans.—To heat 1 pound of water from 100° to 212° requires 112 B. T. U., and to heat 600 pounds requires 67,200 B. T. U. A pound of steam at 100 pounds gauge pressure contains 1,185 B. T. U. above 32°, and $1,185 - (212 - 32) = 1,005$ B. T. U. above 212°. Then, $67,200 \div 1,005 = 66.87$ pounds, nearly, which, at 100 pounds gauge pressure, will, in condensing, heat 600 pounds of water to 212° from a feedwater temperature of 100°. A pound of steam at 100 pounds gauge pressure occupies a space of 3.8 cubic feet; consequently, $66.87 \times 3.8 = 254$ cubic feet of steam that will be needed if all the steam is condensed. This is the theoretical and hence minimum amount. In practice it is rarely possible to condense all of the steam in the heater before reaching the exhaust, as the heating surface is seldom large enough for this. Consequently more steam is required, but the exact amount is very difficult to calculate, owing to variable factors, such as the disposition, kind, and efficiency of the heating surface entering into the problem. Manufacturers of heaters have deduced their own formulas for their heaters from experiment, and we believe it would be better if you were to submit your question to the makers of your heater for a final answer, if it is essential that you should

know exactly how much steam you will need. Incidentally we would remark that it appears to us as if there were an error in your figures as to the pressure of the exhaust of the circulating pump. It seems incredible that this could be 100 pounds.

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(86) (*a*) Is the lining of a tall boiler-house chimney fastened to the outside part in any way, and what is the width of the air space between the lining and the shell? (*b*) How is the crown sheet of a locomotive boiler stayed and supported? Please give me the method followed in most recent practice. J. B., Lonesdale, R. I.

ANS.—(*a*) The lining should always be entirely free from the shell in order that it may expand and contract without straining the shell. The width of the air space may be about 2 inches on top; owing to the batter of the shell it will increase towards the bottom, since the lining is of uniform diameter throughout. Thus, in a chimney 175 feet high and 6 feet inside diameter of the lining, the shell is 8 feet 2 inches diameter at the top and 15 feet 9 inches at the bottom. Owing to the batter the air space increases from 2 inches at the top to 2 feet 9 inches at the bottom. (*b*) The crown sheet is usually supported either by crown bars or by radial stays. Crown bars are specially formed iron girders, the ends of which are so shaped as to form feet. The girders are placed across the firebox with the feet resting on the edges of the side sheets in such a manner as to hold the crown bar a sufficient distance above the crown sheet to assure free access of water to that part of the crown sheet directly below the crown bars. Washers, for holding the crown sheet in position and separating it from the crown bar, are placed between the crown sheet and the crown bar, and the whole is then tightened up and held together by crown bolts which pass up through the crown sheet, washers, and crown bar. The crown sheet is thus supported by the crown bars, which in turn are stayed to the shell of the boiler by means of sling-stays. The crown bolts are $\frac{7}{8}$ to 1 inch in diameter and spaced about $4\frac{1}{2}$ inches centers. In the radial-stay method the crown sheet is supported from the shell of the boiler by means of stay-bolts screwed through both the shell of the boiler and the crown sheet and riveted cold. The crown sheet is given considerable curvature, and the staybolts are then put in as nearly perpendicular to both the crown sheet and the shell of the boiler as possible in order to make them most effective. They are thus set more or less radial in the outer shell, and from that the term radial-stay method is derived. The staybolts are spaced about $4\frac{1}{2}$ inches centers on the crown sheet, which, of course, makes the spaces on the shell of the boiler greater than that amount.

(87) I am running a small saddle-back 10 in. $\times$ 12 in. locomotive, and handle the water with a Metropolitan injector. When the water gets hot in the tank the injector will not work. Can you suggest a remedy? I only carry 100 pounds of steam.
A. H. H., Log Cabin, B. C.

ANS.—If the water in the tank becomes hot it may prevent the injector working in either of two ways. It may prevent the injector raising water in the first place; or, the amount raised may be insufficient and too hot to condense the steam issuing from the forcing valve, in which case the injector will break. In the first case the hot water gives off vapor which prevents sufficient vacuum being formed for the water to be raised. In the second case, the vacuum is formed but is destroyed by the steam that is uncondensed, as soon as the forcing valve is open. It may be that the trouble is due to the water in the suction pipe being too hot. In that case if the injector is converted into a heater for an instant, so as to force the hot water from the suction pipe back into the tank, the pipe will refill with cooler water and the injector will then work. If the trouble is due to the water in the tank being too hot, the tank will have to be refilled with cold water. If the water in the tank becomes hot regularly, better heat insulation should be provided between the tank and the boiler so as to avoid this trouble.

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(88) Referring to the September, 1901, issue of SCIENCE AND INDUSTRY, Question No. 324: (*a*) In question (*a*) Fig. 1, does not the train of gears revolve about the axis of *A* only, and the gear *D* revolve with the shaft held or carried by gear *C*. In other words, am I right in saying that the gears *D* and *C* do not revolve about their own axis? (*b*) Will you give the problem (*b*) in the same question worked out? I have tried it but do not seem to get the same result as you do.
A. P., Waterbury, Conn.

ANS.—(*a*) Gears *B* and *C* do not revolve about their own axis, they revolve about the axis of *A* only. (*b*) The answer referred to is apparently wrong. This is probably due to a misunderstanding of the question. Assume first that wheel *A* makes 30 revolutions in a right-hand direction, while the arm stands still. The wheel *B* then makes $30 \times \frac{75}{60} = 37\frac{1}{2}$ revolutions in a right-hand direction upon its own axis. Assume now that *A* stands still, and the arm makes 40 revolutions about the axis of *A*, and in an opposite, that is, a left-hand direction. The relative motion of *A* and the arm is then the same as if the arm stood still, and *A* made 40 revolutions about its axis in a right-

hand direction. During this time, therefore, B makes $40 \times \frac{75}{60} = 50$ revolutions in a left-hand direction upon its own axis. Since these two motions take place simultaneously, and in each case the wheel B moves in a left-hand direction about its axis, the total revolutions of $B = 37\frac{1}{2} + 50 = 87\frac{1}{2}$. C therefore makes $87\frac{1}{2} \times \frac{60}{45} = 116\frac{2}{3}$ revolutions per minute in a right-hand direction, about its axis. If it is desired to take into account the revolutions of B and C about the axis of A, when revolving with the arm, we add to the above revolutions of B and C, 40 left-hand revolutions. Then B will make $87\frac{1}{2}$ left-hand + 40 left-hand = $127\frac{1}{2}$ left-hand revolutions, and C will make $116\frac{2}{3}$ right-hand + 40 left-hand = $116\frac{2}{3} - 40 = 76\frac{2}{3}$ right-hand revolutions.

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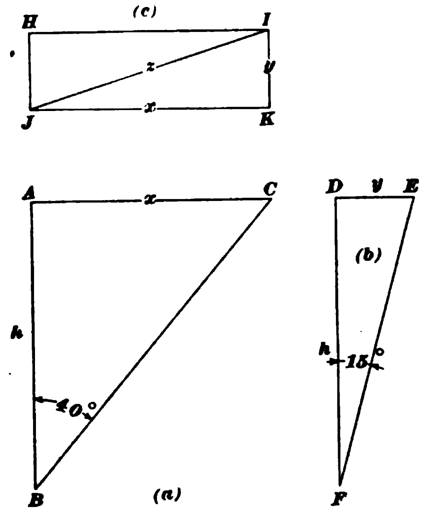
(89) Referring to September, 1901, issue of SCIENCE AND INDUSTRY, Question 321: (*a*) What would be the true angle of the lever and the vertical? It must be somewhat more than 40°, owing to being tilted 15° perpendicular to the 40°. Please explain how



to find the exact degree of the inclination. (*b*) What is designated by vertical line and vertical plane in the same question? (*c*) Please explain method of finding the $77\frac{1}{2}$ r. p. m. of gear B in question No. 324 of the same issue. P. W., Philadelphia, Pa.

ANS.—(*a*) Referring to (*a*) in the accompanying figure and assuming that the actual length of the lever between the points $B\,C$ is 21″, and that the projections on two vertical planes at right angles to each other, represented in (*a*) and (*b*) by the lines $A\,B$ and $D\,F$, make angles of 40° and 15° with these planes as shown, the actual angle between the center line of the lever and a vertical line through B may be determined as follows: Draw $C\,A$ perpendicular to $A\,B$ and $E\,D$ perpendicular to $D\,F$. Draw a rectangle (*c*), making $J\,K = A\,C$, and $K\,I = D\,E$. Join $J\,I$. Let x and y represent the lengths of these lines, h the length of the vertical projections, and z the length of the horizontal projection, as indicated. Then, $x = h \tan 40°$

and $y = h \tan 15°$

$$z^2 = x^2 + y^2 = (h \tan 40°)^2 + (h \tan 15°)^2.$$
$$= h^2 \tan^2 40° + h^2 \tan^2 15°$$
$$= h^2 (\tan^2 40° + \tan^2 15°)$$

But $h^2 + z^2 =$ the square of the actual length of the lever $= \overline{21}^2$. Therefore, $h^2 = \overline{21}^2 - z^2$. Substituting this value of h^2 in the above formula, we have

$$z^2 = (\overline{21}^2 - z^2)(\tan^2 40° + \tan^2 15°)$$
$$= (441 - z^2)(\overline{.83910}^2 + \overline{.26795}^2)$$
$$= (441 - z^2)(.775885)$$
$$= 342.16529 - .775885\, z^2.$$

Then,

$$1.775885\, z^2 = 342.16529$$
$$z^2 = \frac{342.16529}{1.775895}$$

and $$z = \sqrt{\frac{342.16529}{1.775885}} = 13.8805.$$

Let a be the required angle. Then,

$$\sin a = 13.8805 \div 21 = .66098$$

Therefore $a = 41°\ 22'$.

(*b*) A vertical line and a vertical plane are both perpendicular to the plane of the horizon. It will be seen, however, that a vertical plane may contain lines which are not perpendicular to the horizon. The angle which a line makes with the plane, that is, the angle which it makes with its own projection upon the plane, may not be the same as the angle which the line makes with the perpendicular through the point, at which it intersects the plane. (*c*) See answer to Question No. 88.

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(90) Please explain in your columns what mechanical advantage is gained by using wheels on a vehicle. Why does a wagon with large wheels require less power to move it than one with small wheels? Does this apply on smooth tracks as well as on rough roads? How can the difference in force required be calculated?

F. S., Edmonton, N. W. Territories.

ANS.—Let us assume that the track is perfectly smooth, that the coefficient of friction between the wheels and axle and the wheels and track when the wheels are locked is the same, and take three cases; 1st, wheels 72″ diameter; 2d, wheels 36″ diameter, and 3d wheels locked.

Let $W =$ weight on wheels;
$f =$ coefficient of friction;
$d =$ diameter of the spindle in inches;
$D =$ diameter of the wheel in inches.

When the wheels revolve the sliding takes place on the surface of the spindle, and when the wheels are locked, between the rim of the wheel and the track. The resistance to rotation at the surface of the spindle is Wf. In making one revolution this force is overcome through 3.1416 d inches. In the case of the 72″ wheel, the amount of work required for one revolution is $Wf \times 3.1416\,d$ in.-lb. Since the 36-inch wheel must make two revolutions to travel the same distance, the work done is $Wf \times 3.1416\,d \times 2$ in-lb. If now the wheels are locked, the work required to move the vehicle through the same distance is $Wf \times 3.1416 \times 72$ in.-lb. Twice as much work is therefore required in the second case as in the first, and in the third case the work is to the work of the first as the diameter of wheels is to the diameter of the spindle. Under actual conditions, however, the coefficient of friction in the last case is much greater than in the first and second, which makes the difference in favor of the wheels still greater. On rough tracks the advantage of large wheels over small ones is even greater than that indicated above. It will be seen from the above that the force required to move the vehicle is also directly proportional to the diameter of the spindle.

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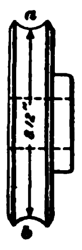
(91) The accompanying sketch shows a worm-gear to cut 28 teeth, $\frac{29}{32}$-inch pitch and 8.12-inch diameter. Is this the correct diameter, and where is the proper place to caliper? Can you give me a rule for figuring the diameter of worm-gears? The rule this gear was figured out with is this: Multiply the number of teeth by the pitch in thirty seconds, or $28 \times 29 = 8.12$ in. Is this correct? G. F. McM., Amsterdam, N. J.



ANS.—The diameter at $a\,b$ is said to be the throat diameter of the gear, and the latter should be calipered at this point. Let p be the circular pitch of the worm-gear, P the diametral pitch, d the pitch diameter, D the throat diameter, and N the number of teeth. Then $d = \frac{p \times N}{3.1416}$, and $P = \frac{N}{d} = \frac{N \times 3.1416}{pN} = \frac{3.1416}{p}$. But $D = \frac{N+2}{P} = N + 2 \times \frac{p}{3.1416}$. We may state these formulas in the form of rules as follows:

Rule 1.—To find the pitch diameter of a worm-gear when the circular pitch and the number of teeth are known, multiply the pitch by the number of teeth, and divide by 3.1416.

Rule 2.—To find the throat diameter when the circular pitch and number of teeth are known, add 2 to the number of teeth, multiply the sum by the pitch, and divide by 3.1416.

For a gear of 28 teeth, and $\frac{29}{32}$-inch pitch, $N = 28$ and $p = \frac{29}{32}$. Then $d = \frac{p \times N}{3.1416} = \frac{\frac{29}{32} \times 28}{3.1416} = 8.077$ in., and $D = (N+2) \times \frac{p}{3.1416} = 30 \times \frac{29}{32} \times \frac{1}{3.1416} = 8.654$ in. The rule and dimension for the throat diameter given in the question are not correct. Formulas and rules for calculating the diameters of worms and worm-gears are given in the Bound Volumes of the Shop Practice Course of the International Correspondence Schools.

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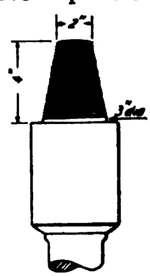
(92) The accompanying sketch shows a pin used for well tools, being screwed into a box to make joints of the several parts of a string of tools. The point is 2 inches in diameter at the small end, 3 inches at the large end, and 4 inches long. Please tell me how much the pin will be weakened by drilling a ½-inch hole through the center longitudinally? F. W., Colusa, Cal.



ANS.—Since the pin is in tension, the amount that it is weakened is represented by the area of the metal cut away. The area of a ½-inch hole = .1963 sq. in. If the pin is made of wrought iron, with an ultimate tensile strength of 50,000 lb. per sq. in., the amount by which the pin is weakened at breaking point is $.1963 \times 50{,}000 = 9{,}815$ lb. Assuming a factor of safety of .10, the safe load is reduced by $\frac{9{,}815}{10} = 981.5$ lb.

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(93) What does the term "wheel base" of a locomotive mean? J. C., Harrison, N. J.

ANS.—The wheel base is the horizontal distance between the centers of the extreme wheels, or the distance measured on the rail between the points of contact of the tires of these wheels. The term "wheel base" without any qualification refers to the whole set of wheels; the term "rigid wheel base" refers only to the coupled wheels or drivers. If some of the tires are without flanges (then said to be *blind* or *plain*) they would not count unless in between other drivers. Thus, suppose a consolidation whose axles taken in order are designated A, B, C, D, and E, and those of the tender F, G, H, and I. The wheel base of the engine is the distance between A and E, measured as above explained. The rigid base is measured

between B and E. If C or D were plain, the rigid wheel base is still B to E; but if B and D both were blind, the rigid wheel base would be from C to E. The total wheel base of engine and tender (an item that has to be often given in connection with turntable capacity) is measured from A to I.

ELECTRICAL

(94) (*a*) If a voltaic cell be allowed to stand for a while, no current flowing, and the elements be then taken out carefully, will the latter be found to contain respectively positive and negative electricity? If so, why cannot the elements of a cell be placed in different vessels, using same kind of solution, and do just as good work when connected up? Or why cannot the same element, as zinc, be placed in different vessels with different solutions, and give good results (using one zinc as +, and the other −)? (*b*) In an induction coil, the E. M. F. is said to be increased by adding more wire to the secondary coil. Does this hold good indefinitely? (*c*) Is there any such thing as negative electricity, or is this only another name for what might be called an electric vacuum?

C. F. G., Rockingham, N. S.

Ans.—It is possible that the elements might have a mere charge of electricity, but after once discharging them you could not obtain any more current from them. Chemical action is necessary to maintain a current. They would not work if placed in separate vessels because there must be a path from one plate to the other through the solution in order that the ions (component parts of a molecule of the solution) which are charged may move and transfer their charges to the elements. We would advise you to read some good book on the elementary principles of electricity and magnetism. You do not understand the elementary principles of electricity. "Elementary Lessons in Electricity and Magnetism," by S. P. Thompson, is as good as any. You can purchase it for $1.40 from the Technical Supply Co., of Scranton, Pa. (*b*) No; this statement certainly does not hold good indefinitely. (*c*) We do not know what electricity is; we only know the various effects that it produces and the laws it follows. Hence, we do not know whether there is either negative or positive electricity. But we certainly do know that if we rub glass with silk that *equal electric charges* are produced on each, and that the glass will attract a third charged body that is repelled by the silk. Therefore, the charged glass and silk produce opposite effects, and if we call the charge on the glass positive, it is logical to call that on the silk negative. Formerly the terms vitreous and resinous were used instead of positive and negative. We do not see how negative electricity can be considered an electric vacuum. A body that apparently has no electric charge, that is, a body in a neutral electric state, is supposed to have an equal amount of both positive and negative electricity, but the two kinds of electricity are intimately mixed together, and hence one neutralizes the effect of the other and the body seems to have no electricity at all. We would strongly advise you to read the book referred to above or some such simple book as the "Elements of Natural Philosophy," by Avery.

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(95) (*a*) Will you kindly explain just what occurs when the field is thrown off a shunt motor? (*b*) Why does the motor speed up? (*c*) Would a heavy load on the pulley hold the speed down and prevent "flashing over," i. e., a jump from one brush to the other across the face of the commutator. This is a 500-volt direct-current motor. W. M. G., Lynn, Mass.

Ans.—(*a*) If the field is thrown off while the armature is left connected to the line, there will be a large rush of current through the armature because the armature has no magnetic field to speak of and therefore cannot generate the counter E. M. F. that limits the current under ordinary working conditions. The field of a shunt motor should never be cut off while the armature is left connected to the line as the violent flashing and burning at the commutator is liable to injure the motor. (*b*) The motor speeds up because the field is very much weakened, in fact the only field present is that due to the magnetizing action of the heavy armature current. The weaker the field the faster the armature has to turn to generate the counter E. M. F. (*c*) You might hold the speed down in this way but there would still be an excessive current and flashing at the commutator. The chances are that the motor would be burned out unless the circuit were opened by a circuit breaker or other protective device.

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(96) (*a*) Please define (1) transformer; (2) compensator; (3) economical coil; (4) induction coil; (5) kicking coil; (6) impedance coil; (7) reactance coil. (*b*) What is their relation to each other, if any? (*c*) What are their functions in an electric circuit? J. C. G., Montreal, Can.

Ans.—(*a*), (*b*), and (*c*) A transformer is a device used for raising or lowering the pressure of an alterating-current circuit with a corresponding change in the current. It consists of a laminated iron core on which two coils are wound these two coils being

entirely separate. One coil, that to which current is applied, is called the *primary*, and the other, from which the current is delivered, is called the *secondary*. If the primary has more turns than the secondary the pressure will be lowered and vice versa. (2) The term compensator is applied to a number of different devices. One of the commonest is a special kind of transformer used for lowering the line E. M. F. when starting induction motors. (3) An economical (economy) coil is a coil wound on a laminated iron core used principally for reducing the line pressure in connection with the operation of arc lamps on alternating-current circuits. (4) An induction coil is practically the same as regards its general features as a transformer. Induction coils are, however, used in connection with an interrupted direct current in the primary instead of a regular alternating current. The core on which the two coils are wound is straight, and the magnetic circuit is therefore open, while in a transformer the magnetic circuit is usually closed. (5), (6), and (7) Kicking coil, impedance coil, and reactance coil are terms that are used to denote the same thing, i. e., a conductor so wound as to have self-induciion. When a varying current flows through such a coil, a counter E. M. F. is set up which tends to choke back the current, hence the name. These coils are used largely in connection with lightning arresters, because they choke back the lightning discharge and compel it to take the path to ground through the lightning arrester.

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(97) (*a*) Would it be practicable to construct a 4- or 6-inch spark coil by one's self? (*b*) Would a 4-inch spark induction coil be suitable for ordinary X-ray work? (*c*) What would it cost to construct such a 4-inch coil? (*d*) Will you recommend some simple, concise book on wireless telegraphy? (*e*) What is the smallest sized coil, capable of transmitting signals by wireless telegraphy? (*f*) How far would a 4-inch spark induction coil transmit a signal? (*g*) Can the necessary wireless apparatus be constructed by oneself.

A. B., Bellevue, Pa.

Ans.—(*a*) Yes, provided you have the use of a lathe or winding machine. It would be extremely slow work to wind the secondary coil by hand. (*b*) A 4-inch spark coil might do, but we would advise at least a 6-inch, and preferably an 8-inch spark coil. (*c*) If you will get some such book as "Ruhmkorff Induction Coils," by H. S. Norrie, price 50 cents, you can probably figure the cost yourself. It will depend on how much you pay for your wire and other materials and the amount of work you will have to have others do for you, so that we cannot very well figure how much it would cost you. (*d*) "Wireless Telegraphy Popularly Explained," by Richard Kerr, price 75 cents, explains the principles of wireless telegraphy and the construction of a coherer. "Ruhmkorff Induction Coils," by Norrie, tells how to make induction coils, X-ray, and wireless telegraph apparatus. You can purchase these books from the Technical Supply Co., of Scranton, Pa. (*e*) This would depend on the distance, the arrangement, efficiency, and sensitiveness of the apparatus. We cannot give any definite figure. However, we would not advise any smaller than an 8-inch coil. Marconi uses, we believe, at least a 10-inch coil even for very short distances. This does not imply, however, that a 10-inch spark is used, in fact the spark gap used is seldom over 1 inch; but a large coil is necessary to get a sufficiently vigorous discharge. (*f*) We cannot answer this question for the reasons just given. (*g*) See answer to (*a*). We hardly know whether you could make a coherer yourself, and we doubt if you could make a satisfactory relay. These you can buy, however, separately.

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(98) (*a*) Will you kindly explain how it is that a millivoltmeter is used for indicating the amperes being measured in a circuit? Is it because 1 ampere of current being used on a circuit reduces the pressure by $\frac{1}{10}$ volt? (*b*) What could the two sides of a circuit, which with direct current are called positive and negative, be properly called with alternating current? (*c*) What would they be called in an alternating three-wire system, the two outside wires being from the same wire of the transformer, the center wire being from the other wire of the transformer? This is unlike the Edison three-wire D. C. system where, as I understand it, the outside wires are from different sides of two machines, the central wire being the positive of one machine and the negative of the other, and the two currents tending to neutralize each other. The current flowing in the neutral wire is governed, so to speak, by the current being consumed on the two sides of the three-wire system. Am I right in my view?

E. H. O., Philadelphia, Pa.

Ans.—(*a*) When a millivoltmeter is used to measure current, the current is sent through a low resistance and the millivoltmeter is connected across the terminals of this resistance or shunt as it is called. The pressure across the shunt is proportional to the current flowing, and this pressure causes the deflection of the millivoltmeter, the deflection being proportional to the main current, or, looking at it in another way, a small proportion of the main current flows through the voltmeter and the greater part through the shunt. Since the resistances of the voltmeter and shunt are fixed, it

follows that the current in the voltmeter, and hence its deflection, will be proportional to the main current. (*b*) The terms positive and negative, or in fact any similar terms, cannot be applied to an alternating-current circuit, because the current is reversing periodically. In connecting up transformers, however, it is important to consider the instantaneous polarity of the wires, and hence the wires are often spoken of as positive or negative simply to distinguish their relative polarities at a given instant so that connections may be properly made. (*c*) The alternating system you refer to, where the two outside wires are connected to the same terminal of the transformer, is not a three-wire system in the true sense. It is a modified two-wire system with simply two wires instead of a single wire carried from one terminal. This arrangement is sometimes used for convenience, but it is essentially a two-wire system. You appear to have the correct idea regarding the Edison three-wire system. The current in the neutral wire is the *difference* between the currents in the outside wires, and its direction of flow depends on which side is loaded the heavier. In the system you describe above, the current in the middle wire is equal to the *sum* of the currents in the outside wires.

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(99) (*a*) Please explain electromotive force as applied to an electrical circuit. (*b*) Which is the best way to obtain an engineer's position, to gain experience through the fireroom and work up to the position of engineer, or to obtain a machine shop experience? (*c*) Is the stationary engineering profession being supplanted by the electrical profession?

J. S. B., Buffalo, N. Y.

ANS.—(*a*) When an electric current flows through a conductor, against the resistance of the conductor, there will always be a difference of potential between the ends of the conductor. If a direct current of 5 ampheres flows through a conductor having a resistance of 2 ohms, a voltmeter connected across the terminals of the conductor will indicate $2 \times 5 = 10$ volts, the E. M. F. between the ends of the conductor being equal to the product of the current in amperes and the resistance in ohms. This will be so if the conductor forms part of the positive wire of a line, or part of the negative wire of a line. Consider ten 10-ohm coils connected in series between the terminals of a 100-volt dynamo. A current of 1 ampere will flow through the coils, and as each has a resistance of 10 ohms, there will be an E. M. F. of 10 volts across the terminals of each coil. Between the negative terminal of the dynamo and the distant end of the coil connected to it there will be an E. M. F. of 10 volts; between the terminal and the end of the second coil, 20 volts, and so on, till we reach the end of the 10th coil, which is connected to the positive terminal of the dynamo, the E. M. F. between the negative terminal and this point being 100 volts. We thus see that the E. M. F. of 100 volts is expended in forcing current through the resistance of the 10 coils in series, and that a reading on a voltmeter may be obtained by placing the voltmeter terminals on separate points on the same circuit. (*b*) The best engineer is the one who has had a fireman's experience combined with a general knowledge of machine shop practice. (*c*) No; we do not think one profession is supplanting the other, but both are growing rapidly and are becoming more intimately associated.

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(100) (*a*) Suppose an alternating current of 60 cycles is flowing in a 100-mile circuit. Does the current pass out on one line and return on the other in $\frac{1}{60}$ of a second? (*b*) Is the rate of flow of current the same in both the primary and secondary coils of a transformer, if the coils are wound for different E. M. F.'s at their terminals? (*c*) What size of storage battery would be required to operate 60 incandescent lamps and 2 arc lamps for 3 hours? How can such a battery be made? (*d*) Why are ground circuits not used for lighting work, the same as for traction purposes?

F. H. P., Coffinville, Kan.

ANS.—(*a*) No; electromagnetic waves travel at the rate of 192,000 miles per second, approximately. The speed of current propagation in a wire is less than this, as the wire offers impedance to the rate of flow of current due to its resistance, self-induction, and capacity. The speed is, however, very great, and an impulse impressed on one end of a 100-mile circuit reaches the other end in an almost inappreciable length of time. (*b*) No; if the E. M. F. of the primary coil, the current in this coil, the E. M. F. of the secondary coil, and the efficiency of the transformer are known, the current in the secondary coil can be found by multiplying the primary E. M. F. times the primary current by the per cent. efficiency and dividing by the E. M. F. of the secondary coil. The watts input of the primary coil, multiplied by the per cent. efficiency, equals the watts output of the secondary coil. By dividing the watts output of the secondary coil by the secondary E. M. F., the current in the secondary coil is obtained. (*c*) Allowing 5 amperes each for the 2 multiple arc lamps and 30 amperes for the 60 incandescent lamps, the least ampere hour output of the cells must be $40 \times 3 = 120$. The number of cells for a 110-volt circuit would be 55. We cannot undertake to give details of the construction of a storage battery of this size in these columns. An

article on "How to Make a Storage Battery" appeared in the June, 1900, number of this magazine. The article describes the construction of a small cell. (*d*) Lighting circuits enter houses, and there is much more danger to human life from shocks and liability of fire from grounded circuits than from well-insulated metállic circuits.

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(101) (*a*) I have a small plant operated by two 4-horsepower motors, one an old one running at 1,500 r. p. m., and the other a new one running 600 r. p. m. Would there be any saving in the power bill by replacing them by one 8-horsepower motor? (*b*) Could I use a 1-horsepower motor for a generator; if so, how many 16 c. p. lamps will it run? (*c*) I have in the polishing room a blower used to carry away the dust from eleven wheels, varying from 6″ to 9″ in diameter. The wheel bonnets are connected by 3″ pipes to a main pipe 8″ in diameter, which goes direct to the blower. The blower is not large enough to carry away the dust. What size blower ought I to have to give good suction to all the wheels?

H. M., Hoboken, N. J.

Ans.—(*a*) Yes; there would be some saving because the efficiency of the single large machine would be higher than that of the two small ones. The amount of saving would depend upon whether or not you kept the 8-horsepower motor well loaded. If you installed a large motor and then ran it considerably below its capacity there would not be much advantage gained by installing it. (*b*) Yes; if it is a shunt-wound or compound-wound machine. About nine or ten 16-c. p. lamps. (*c*) This depends very much on the layout of the plant, number of bends in the pipe, etc. The blower should be large enough to produce 4- to 5-ounce pressure, but we cannot state definitely the size of blower required. We would advise you to write to the makers of the blowers giving them a sketch of the layout of your plant. They will then be able to advise you as to the best size to use. If your fan is not already running at its maximum allowable speed, it might be a good plan to try speeding it up.

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(102) (*a*) If an electric light plant were to be installed in a city of 5,000 to supply 3,500 16-candlepower lamps, and when the load goes down less than one-half by 12 P. M., would it be best to have a single engine and dynamo or two smaller engines and two dynamos? Alternating current to be used. (*b*) Taking expense of installation and running expense into account which would it be better to install, slow-speed engines in large units or small high-speed units? (*c*) Can you refer me to a book on polyphase alternating currents, motors, line work, house wiring, and transformers?

I. R. S., Raton, N. Mex.

Ans.—(*a*) We think it would be better to install two units, either of which can carry a good part of the load in case the other should break down. In a lighting plant every precaution should be taken to have the service continuous, and if dependence is placed on a single unit there is liability of interruption. (*b*) For a small alternating-current plant we would recommend belt-driven units, driven by automatic cut-off engines. The dynamos would be belted directly to the flywheel of the engines. (*c*) Electric Lighting, by Prof. Crocker, 2d Volume, Technical Supply Co., Scranton, Pa.

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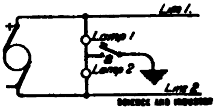
(103) (*a*) Is the plan of wiring for the ground detector shown in accompanying figure correct? (*b*) If there is a considerable leak, will lamp No. 2 burn brighter in proportion to the leak?

W. S., Seattle, Wash.

Ans.—(*a*) The plan of wiring that you sent is practically like the figure shown here, except that the push-button switch *s* is here placed in the ground wire instead of between line *1* and lamp *1*, as in your figure. With the switch between line *1* and lamp *1*, as in your figure, there would always be a ground on line *2* through lamp *2*, which is not desirable. As here connected, current is always flowing through the two lamps in series, but the current in this case is quite small and is not, therefore, a serious objection. (*b*) Assume the switch *s* to be closed; then, if there is a leak to ground on line *1*, lamp *2* will burn brighter in proportion to the amount of current that leaks to ground from line *1*; this current is shunted around lamp *1* by the lower resistance of the ground path. Similarly, if there is a leak to ground on line *2*, then lamp *1* will burn brighter as the escaping current increases in strength. If there is a ground of about equal resistance on both lines, then both lamps will glow equally. By turning out one lamp, the other will continue to glow, showing that there is a ground on the opposite line, that is, if lamp *2* continues to glow when the circuit through lamp *1* is open, there is a ground on line *1*.



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(104) Will you please tell me how to arrange an electric light to be operated by using gravity cells?

F. H. Y., Pottsville, Pa.

Ans.—It will be very expensive to operate an incandescent electric light by gravity cells and the first cost will also be high. For instance, an 8-candlepower lamp requires

about 28 watts, or about 1 ampere at 28 volts. Assuming the internal resistance of gravity cells to be 3 ohms and electromotive force 1.1 volts per cell, which is about what practice indicates, you would require 306 gravity cells, arranged in 6 parallel rows with 51 cells in each row. The lamp would be connected in series with the battery. We have allowed practically nothing for the fall of potential in the connecting wires in calculating the number of cells given above. The gravity cells alone, at 55 cents per cell, would cost you $168.30. It is never economical to use primary batteries for lighting incandescent lamps, except very small ones indeed, nor advisable if it is possible to secure current from electric light or power mains, a dynamo, or storage battery.

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(105) (*a*) What kind of storage cells give the largest watt output for total weight of cell, i. e., cells that are used commercially? (*b*) What is the normal and maximum discharge rate of the copper-zinc (Philips-Enty) cell per square inch surface of plates? (*c*) In forming the copper plate, could sheet copper, made porous, be made to answer instead of porous wire woven into mats? (*d*) Are these cells patented? (*e*) Please give address of Waddell-Enty Manufacturing Co. and others who make light batteries for traction work. (*f*) Name best books on storage-battery calculations.

G. C. C., Phœnix, Ariz.

ANS.—(*a*) The cells that have been used most largely for traction work are of the lead-sulphuric acid type. Their output per pound of weight is not as large as that of the copper-zinc type, but the latter cells seem to be so liable to local action that they have not been a commercial success. One great objection to the copper-zinc cell is that the electrolyte has to be worked at a comparatively high temperature. The new Edison storage battery, which is an iron-nickel cell, is claimed to have over twice as great an output per unit weight as the lead cell. They have not yet been used commercially, so that their cost of maintenance as compared with the lead cell cannot be stated. (*b*) We have been unable to find any data relating to the discharge rate per square inch of these elements. Treadwell gives the capacity as 19 ampere hours per pound of cell complete; voltage .8. (*c*) We see no reason why such a plate could not be used provided it were mechanically strong and presented a surface equally as large as that of the copper mat. (*d*) Yes. (*e*) We are under the impression that this firm is not now in existence. Their address was formerly The Waddell-Enty Co., Bridgeport, Conn. Other makers are The Gould Storage Battery Co., 25 West Thirty-third street, New York; Sipe & Sigler, makers of the Willard storage battery, Cleveland, Ohio; Electric Storage Battery Co., Philadelphia, Pa. (*f*) "The Storage Battery," by Treadwell, Technical Supply Co., Scranton, Pa.

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(106) What effect will a decrease in the line E. M. F. have on the amount of current taken by a shunt motor and by a series motor?

G. J. R., Nashville, Tenn.

ANS.—With either a shunt-wound or a series-wound motor a decrease in the E. M. F. impressed on the motor terminals causes a decrease in the speed, and with an ordinary load, if the speed at which the load is driven is lessened, the load or power delivered by the motor is lessened, and therefore the watts of electrical energy needed by the motor reduced in value. The number of watts needed for the load has been reduced, but so has the number of volts. Whether the current has been decreased or not depends on the relative changes in the value of the watts load, or power delivered, and the terminal impressed E. M. F. If the power delivered falls off rapidly as the speed decreases, the current taken by the motor will probably be less than when the E. M. F. was at its maximum value. If the load is of such a nature that it either does not fall, or falls but little, with the decrease of E. M. F. and speed, the current taken by the motor will be more than when the E. M. F. is at its maximum value. In the case of series motors on a car, at the end of a long line, where the E. M. F. between trolley and ground is low, the car motors may take more current from the line than when the E. M. F. is high, because the motors are run longer in multiple and the controller handle is moved more quickly from notch to notch in the motorman's endeavor to make good time under the faulty condition of low E. M. F. We have omitted consideration of any change in efficiency which might take place in the motors.

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(107) (*a*) How may a small 10-volt 5-ampere Elecktron motor be used as a dynamo? (*b*) What is the address of the Elecktron Mfg. Co.?

W. D. P., Manasquan, N. J.

ANS.—(*a*) If this motor is a series-wound motor we do not think that you can use it successfully for a dynamo, unless you separately excite the field coil by a cell of battery. If it is a shunt-wound motor, do not alter the connections between the shunt-field terminals and drive the armature in the same direction as its direction of rotation when acting as a motor. (*b*) Elecktron Mfg. Co., Springfield, Mass.

(108) Please explain the construction of a method of using junction boxes. Describe particularly the four-circuit cut-out box, illustrated in the Sprague Electric Co.'s catalogue No. 404 on page 123. The point which confuses me most is the position of the binding posts. Why are they not placed alternately + and —?

J. B. F., Cincinnati, Ohio.

ANS.—Junction boxes are used in electric wiring work to protect and hold cut-outs. Cut-outs must be placed on all service wires, either overhead or underground, as near as possible to the point where they enter the building and inside the walls, and arranged to cut off the entire current from the building. They must be placed at every point where a change is made in the size of wire (unless the cut-out in the larger wire will protect the smaller). No set of incandescent lamps requiring more than 660 watts should be dependent on one cut-out. There are many styles of junction boxes. These boxes that are designed to hold the various forms of cut-outs required in electrical wiring. The cut-out to which you refer is designed to be installed with junction box No. 905, page 82. The two main wires run through the box and are connected to the cut-out by means of the two large binding screws near the center of the cut-out. One binding clamp is connected to the line of small connecting screws on one side of the cut-out, and the other binding clamp is connected to the other connecting screws. In direct-current work, all of the positive wires of the four branch circuits are connected on one side of the cut-out and pass out of the four holes, on one side of the junction box. See No. 905. All the minus wires of the four branch circuits are connected to the branch terminals on the other side of the cut-out and pass out of the junction box through the four remaining holes. The wires can be paired off after leaving the box. By this arrangement of the cut-out, terminals between which there is a great difference of potential are placed some distance apart, and there is therefore less danger of trouble.

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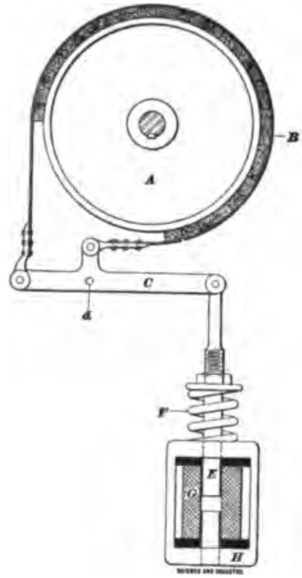
(109) Please tell me how to make a solenoid to operate a brake on an electric crane so that the load will not run down when the current is off. I am advised that they are connected in series with the field windings. The motor I have is 110-volt series-wound, capacity 15 tons. The brake wheel is to be on the armature shaft.

P. M. M., Philadelphia, Pa.

ANS.—The accompanying figure shows one method of arranging a brake solenoid. *A* is the brake pulley and *B* the band brake lagged with wood. *C* is a lever hinged at *d*. The plunger *E* of the solenoid is attached to one end of *C*, as shown, and the solenoid pulls against the adjustable spring *F*. When the magnet is energized, *C* is pulled down and the brake is released; and when the current is cut off from the magnet, spring *F* forces *C* up and sets the brake. The solenoid is provided with one coil *G* surrounded by the cast-iron yoke *H*. Sometimes the coil is connected in series with the field, but more often it is connected directly across the circuit by itself and is arranged so that it will be excited at the same time as the shunt field, thus releasing the brake before current flows through the armature. We think this would be the better plan in your case, because the shunt field



of your motor has not been designed with the view of having this extra coil connected in series with it. From the data which you give we have no means of telling the pull which the solenoid would have to exert; in fact, the only safe way is to construct the brake and determine the necessary pull by experiment. A solenoid about 8 inches long with a 1¾-inch core would no doubt be strong enough. The yoke *H* should have a cross-section at least as large as the wrought-iron core *E*. You will find full directions for designing the winding of a solenoid of this kind in the April and May, 1901, numbers of the "American Electrician."

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(110) (*a*) Please give information in regard to constructing a small dynamo for use in removing warts, moles, etc. Should the machine have an E. M. F. of about 10 volts and be so wound that it would furnish a very steady current? Please state amount of

wire and style of machine best adapted for this work. A carbon rheostat is to be used in connection with the dynamo. (*b*) Can vulcanized rubber be dissolved by benzole?
A. C. H., Milwaukee, Wis.

ANS.—(*a*) We cannot undertake to design special apparatus. See the notice at the head of "Answers to Inquiries" column. In general we would say, that you should make a small shunt-wound, bipolar dynamo. Have as many commutator segments and coils as possible, so that the current will be nearly steady. Only a very small current is required. An E. M. F. of 10 volts would be suitable. (*b*) Yes.

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(111) I want to construct a small 30-volt, 2-ampere dynamo. Is the following data about correct? Speed 2,000 revolutions per minute; 3″ diameter by 2¼″ long armature core with 12 slots ⅜″ × $\frac{5}{16}$″; winding for each slot 36 wires; No. 18 B. & S.; field cores of cast iron, 2″ diameter by 3″ long; each field coil wound with 936 turns of No. 18 B. & S. wire; bipolar shunt wire.
W. J., Saginaw, Mich.

ANS.—We cannot undertake to calculate winding for special apparatus. See notice at the head of these columns. The data you send is not sufficient for very accurate calculations. We would suggest that you might obtain the desired E. M. F. at a lesser speed by using No. 20 wire for the armature coils and No. 24 for the shunt coils. The general arrangement of the dynamo and the number of slots in the armature would seem to be about correct.

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(112) What causes a 20 K. W. 220-volt direct-current dynamo to at times send out a small ring of sparks which completely encircle the commutator. This occurs usually on the commutator face about 1 inch from the outside end, but sometimes shows the same distance from the inside end. Touching up the commutator with commutator compound will always start this stream of sparks and then if the commutator is touched the sparks will cease. The commutator is in fine condition and the machine gives no trouble whatever.
F. G. F., Plankington, S. D.

ANS.—This sparking is due to small particles of dirt that bridge over between the commutator bars. Commutator compound usually contains graphite and small particles of this will cause these fine sparks by connecting adjacent bars and by drawing out small arcs from the brushes. These fine sparks do no harm whatever and do not indicate any defect in the machine. They are nearly always present when carbon brushes are used. If they become very numerous wipe off the commutator with a piece of hard canvas.

(113) (*a*) I have installed a watt meter registering in kilowatt-hours. With the dial indicating 6 kilowatts is not the correct reading on the meter at this point 6,000 watt-hours and 120 ampere-hours, the voltage being 50? (*b*) In installing an electric light plant in a town of 3,000, would you not recommend a 110-volt 3-wire secondary system with a frequency of 16,000 alternations? (*c*) If you have the space will you explain what is meant by *phase* and the difference between one, two, and three phase machines? F. P. S., Cantar, Mo.

ANS.—(*a*) Most recording watt meters read in watt-hours not kilowatt-hours, each division on the lowest dial corresponding to 100 watt-hours and one complete revolution to 1,000 watt-hours or 1 kilowatt-hours. If, however, your meter reads in kilowatt-hours a reading of 6 would be equivalent to 6,000 watt-hours and if your voltage were maintained constant at 50 volts, this would be equivalent to 120 ampere-hours. (*b*) By a 110-volt three-wire system we take it to mean that you would use 110 volts between the middle and the outside wires and 220 volts between the outside wires, two transformers with 110-volt secondaries being used. This would make a good system of distribution for the business part of the town. The residence portion, where the lighting is scattered, could best be supplied by individual transformers. A frequency of 16,000 alternations is suitable if your work is confined to lighting. If it is the intention to operate motors, it would be better to use a lower frequency, say 7,200. (*c*) You will find a full explanation of phase difference in the series of "Simple Lessons in Alternating Currents," which began with the June, 1901, number of SCIENCE AND INDUSTRY. The subject of phase difference was explained in the December, 1901, number. A single-phase machine delivers a single alternating current. A two-phase machine delivers two currents, one lagging behind the other by one-quarter of a cycle. A three-phase machine delivers three currents that lag one-third of a cycle behind each other.

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(114) (*a*) Please show by a sketch how a shunt motor is wound. (*b*) Also please show winding of fields.
J. L. P., Pittsburg, Pa.

ANS.—(*a*) and (*b*) Shunt motors are wound in the same way as shunt dynamos, so that the information relating to shunt dynamos in standard works on the subject may be taken as applying to shunt motors as well. There are a great many different types of windings suitable for shunt motors, depending on the number of poles, voltage, etc., and your best plan would be to read up the subject in a book such as "Dynamo-

Electric Machinery," by Silvanus P. Thompson. You will find this in almost any public library. The armature winding shown in the January, 1902, number, Answers to Inquiries, No. 18, is suitable for a two-pole shunt motor. The field coils of such motors are connected in series so as to form poles alternately north and south around the armature, and when the motor is in operation the fields are connected across the line.

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(115) In a 110-volt incandescent circuit A tested the circuit for a ground and got 85 volts from one side of the line, and practically zero from the other. A claims that there is no loss in the circuit as but one side is grounded; B claims that there is a loss equal to sixteen 16-candlepower lamps. Who is right? If B is right, how can he tell what the loss is by simply knowing the voltage of the machine and ground, without knowing the resistance of the voltmeter and having no other data?

X. Y. Z., Garden, Mass.

ANS.—A is right. If only one side of the circuit is grounded there can be no loss of current because it requires two grounds to complete the circuit for the leakage current. In order to calculate the resistance of the ground, it is necessary to know the resistance of the voltmeter.

***

(116) Will you please explain to me the difference between current and electromotive force? In the answer to question No. 418 in the November, 1901, issue, this point is explained, but I do not understand it. S. S. M., San Francisco, Cal.

ANS.—Electromotive force is the pressure that causes a current to flow in an electric circuit while the current is the result of the electromotive force. For example, a dynamo or battery generates an electromotive force and if a circuit is established between the terminals of the battery or dynamo, a current will flow. It is possible, therefore, to have an electromotive force present without there being any current, but it is impossible to have a current without an electromotive force. An electromotive force might be present but if there were no closed circuit for the current to flow through, no current could be set up. Take the case of water supplied from a reservoir situated at a distance above the point where the water is supplied. There will be a pressure in the pipe system due to the head of water and this might be taken to correspond to the electromotive force. If the pipe were opened at some point a current of water would flow, this current being set up by the water pressure but the pressure would still exist in the piping whether a current were allowed to flow or not.

MISCELLANEOUS

(117) I wish to know how to find the proper spacing of stringers for a given floor load. Assume that the stringers have a span of 10 feet, and that ordinary 5″ matched flooring is used. How close would it be necessary to place the stringers and what size would be required to support 250 pounds at the center?

E. K., Milwaukee, Wis.

ANS.—The stringers of which you speak can be nothing more than joists when ordinary 1″ × 5″ matched flooring is used; the character of the flooring determines the distance apart that the joists or girders may be placed. It is not usual to space joists further apart than 16″ to 24″ when flooring 1″ thick is used. Where heavy metal construction is adopted and tongued and grooved flooring 3″ or 4″ in thickness is employed, the girders may then be placed from 4 to 8 feet apart. Where the flooring has sufficient strength to carry the load between the girders, they may be placed at such a distance apart that their maximum transverse strength will be realized. The safe load that any rectangular girder loaded at the center will support may be found by the formula, $W = \frac{s\,b\,d^2}{18\,L}$, in which s is the allowable strength value, or modulus of rupture, as it is called, for the particular timber; b is the width of the beam in inches, d the depth, also in inches, and L is the span of the girder in feet. The weight W is in pounds. The value of s is different for the several timbers used in construction, and may be obtained from the following table:

White Oak	1,500
White Pine	1,000
Georgia Yellow Pine	1,800
Oregon Pine	1,625
Northern Yellow Pine	1,250
Spruce	1,000
Hemlock	900

In the application of the above formula assume that a spruce joist 3″ × 12″ has a span of 18 feet. By substitution in the formula, $W = \frac{1{,}000 \times 3 \times 12 \times 12}{18 \times 18} =$ 1,333 pounds, which is the amount of the concentrated load at the center that such a joist would safely support. The span which you mention in the inquiry is so small and the load to be carried so little, that it can be readily supported by a 2″ × 6″. It is usual in figuring the size of girders or joists for the support of floors, to consider the load as uniformly distributed. The simple girder supported at both ends

will support a uniformly distributed load twice as great as a concentrated load applied at the center.

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(118) (*a*) Would you advise the construction shown in Fig. 1? I desire to excavate below the old cellar bottom for a boiler room, as designated, and wish to know whether underpinning should be employed rather than this construction, and also what the slope of the retaining wall should be, and its thickness. (*b*) What books would you recommend which treat upon office building construction, such as steel-beam connections, terra-cotta work, and the manner of securing it to the skeleton construction for the exterior screen walls and the projecting balconies? (*c*) If the proper projection for a building 30 feet high is 8 inches, is it correct to have the projection of a building 90 feet high in the same ratio, or 24 inches? J. M., Belleville, Ill.

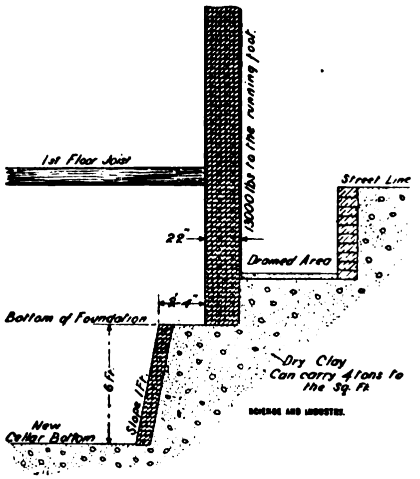


FIG. 1

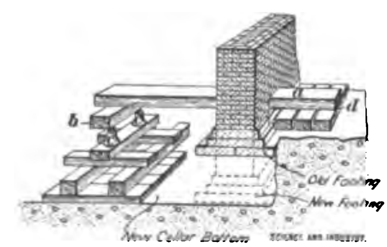


FIG. 2

ANS.—(*a*) You could not use the construction shown in Fig. 1 with safety; the retaining wall is entirely too light, and besides the design is dangerous. It would be far preferable to underpin the wall as shown in Fig. 2 and to extend the footings down to the new cellar bottom. In this figure the needle beam is shown at *a* and should be supported upon the straining beam *b*, which is held up by the jacks *c c*. The temporary grillage *d* should be placed as far back from the excavation as the transverse strength of the needle beam will allow. If the scheme shown in Fig. 1 must be adhered to, the retaining wall should be kept inside the building wall a distance such that a line drawn from a point one foot inside of the bottom edge of the foundation footing and at an angle whose sides are parallel with those of the angle of repose composing the foundation soil, will intersect the cellar bottom and not the inside line of the retaining wall. The retaining wall should have a thickness at the base equal to $\frac{4}{10}$ of the height. The thickness of the wall at the top should not be less than $\frac{1}{6}$ of the height of the wall, and the stability of the wall, especially in clayey soil, is somewhat increased if the latter is on the side of the wall next to the soil. The conditions for safe construction are designated in Fig. 3. (*b*) "Skeleton Construction in Buildings," by William H. Burkmire, price $3.00, and "Architectural Engineering," by Joseph Kendall Freitag, price $2.50. Both of these may be obtained from the Technical Supply Co., Scranton, Pa., for the price quoted. (*c*) Your inquiry is not clear and we are uncertain as to what information you require. We presume that you speak of the projection or increase in the thickness of walls for brick buildings. If this is so, we would say that no such consideration as suggested can exist, because the purpose of the building, the length of the wall and the number of openings in it, are all factors in determining the thickness, and, consequently, the projection at the several stories. The best rules for proportioning brick walls are found in the recent New York Building Laws. These laws are of interest to every architect, builder, and engineer, and may be obtained in book form for $3.00, purchasable from the Technical Supply Co., Scranton, Pa.

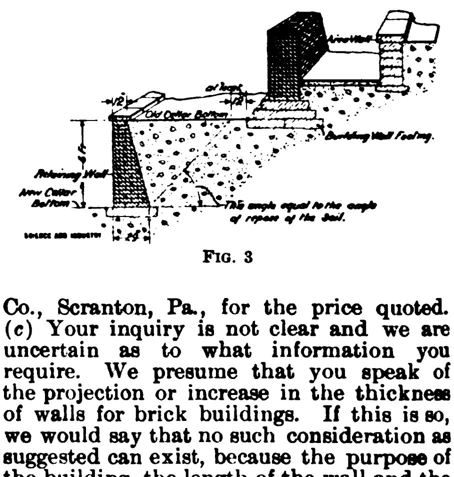


FIG. 3

(119) When the height of the segment and the length of the chord are known, give rules for finding: (a) the length of the arc, (b) the area of the segment.

L. O. W., New York City.

ANS.—(a) Let h = height of the segment, and b = one-half the chord. Then the chord of half the arc is $\sqrt{h^2 + b^2}$. Now, let b = the chord of half the arc, a = the chord of the whole arc, and l = the length of the arc. The length of the arc is given by the approximate formula, $l = \frac{8b - a}{3}$. This formula, known as Huygen's formula, gives the length of any arc less than one-sixth the circumference correct to four figures, it gives the length of any arc less than one-third the circumference correct to three figures, and it gives the length of any arc less than a semi-circumference correct to two figures. The formula is equivalent to the rule: *From 8 times the chord of half the arc, subtract the chord of the whole arc, and divide the remainder by 3. The quotient is the length of the arc, approximately.* (b) The area of the segment is given by the following approximate formula:

$$\text{area of segment} = \frac{4h^2}{3}\sqrt{\frac{a^2}{4h^2} + .392}.$$

This formula gives the area of any segment less than a semi-circle correct to 3 figures. The formula is equivalent to the rule: *Divide the square of the chord by 4 times the square of the height of the segment; add .392 to the quotient, and find the square root of this sum. Now multiply this root by ⅘ of the square of the height of the segment and the product will be the approximate area of the segment.*

***

(120) (a) Can you give me a general idea of the construction of a flexible shaft to run a 3-inch buffing wheel from a Westinghouse fan motor? (b) How is the shaft of a fan motor fastened to the armature spider, and what is the number of revolutions per minute the average fan motor makes? (c) I would like to get the dimensions and pattern for a pressure blower, to be operated from a fan motor, to work a gas blowpipe, the air jet of which is about one-sixteenth of an inch in diameter.

A. R., St. Louis, Mo.

ANS.—(a) The simplest flexible shaft is a long helical spring made of piano steel wire. (b) The armature core or spider may be fastened in different ways, depending on the construction. If the core has a regular hub, the shaft is made a tight fit and forced into the spider and held there by a small set-screw coming flush with the hub. In other cases the core disks are clamped between end plates, which are threaded on the shaft. Another method is to press the shaft in place and run a small pin through the shaft and hub. Keys are not generally used with these small motors. The speed varies from about 1,100 to 1,700 revolutions per minute. Most fan motors are provided with a regulating device, which will admit of this range in speed. (c) It is impossible for us to give you this information with the data at hand. We should advise you to communicate with the manufacturers.

***

(121) Please inform me where I can secure a respirator for paint mixers to keep paint dust out of the nose and mouth, and give me any information that you can in regard to them. P. O. M., Toronto, Ont.

ANS.—There are but few respirators on the market, and it may be fair to the purchaser to state that perhaps not one of these is faultless. It is a difficult matter to fit an appliance to the face so closely as to insure the wearer against the possibility of dust penetrating where this is joined on the face, because of strong suction resulting from inhalation. Another reason is on account of the dissimilar anatomy of the human face and also of the desire for comfort rather than protection. The pressure with which this should be held in position would cause the wearer great discomfort were he compelled to wear a respirator for several hours at a time. We would recommend that the inquirer correspond with any large jobber in surgical instruments, where he may procure the best varieties of respirators on the market, or through such a house he could get in close touch with the manufacturer of these appliances and have one especially constructed to his order. Kuy-Scheeper Company, New York City, are jobbers in surgical instruments and carry a complete line of respirators. These they would doubtless furnish a purchaser for inspection at his request.

***

(122) (a) A man, dying, leaves to his widow and three sons 640 acres of land in the form of a circle. His will provides that each son shall receive one of three equal circles, the largest that can be inscribed in the 640 acres, and that the widow shall receive the remainder of the 640 acres. Find the radius of the circle which each son receives. (b) A ball 18 inches in diameter is in a corner. What is the diameter of the largest ball that can lie on the floor behind this one, both touching the same walls? H. K., 83 Cummings Ave., Grand Rapids, Mich.

ANS.—(a) Let $R = o\,a'$ the radius of the large circle (see figure), and $r = a\,a'$ the radius of the inscribed circles. The triangle $a\,b\,c$ is equilateral and each side $= 2\,r$. The triangle $a'\,b'\,c'$ is also equilateral. The triangle $o\,b\,c$ is similar to the triagle $o\,b'\,c'$.

Therefore,

$$\frac{b'c'}{bc} = \frac{ob'}{ob}, \text{ or } \frac{b'c'}{2r} = \frac{R}{R-r}.$$

Whence, $$b'c' = \frac{2Rr}{R-r}. \qquad (1)$$

The point o where the medians of the triangle $a'b'c'$ meet is $\frac{2}{3}$ of the distance from a' to h.

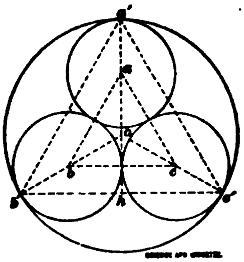
Hence, $$a'h = \tfrac{3}{2}R. \qquad (2)$$

But, $$ah' = \sqrt{\overline{a'c'}^2 - \left(\frac{b'c'}{2}\right)^2}. \qquad (3)$$

Substituting values from (1) and (2) in (3) and solving,

$$r = .4641016\,R.$$

Now the radius of a circle which contains 640 acres is 992.9725 yards. Hence, r the required radius is .4641016 times 992.9725 yards, or correct to three decimal places,



460.84 yards. (*b*) From the center of the larger ball to either wall is 9 inches. Let $R = 9$ inches. Hence, from the center of the larger ball to the corner is $\sqrt{3R^2} = R\sqrt{3}$. Subtracting from this the radius of the ball gives $R\sqrt{3} - R = R(\sqrt{3}-1)$, the distance from the corner to the surface of the ball (in the direction of its center). Let r = radius of smaller ball. Then from its center to the corner is $r\sqrt{3}$, and $r\sqrt{3} + r = r(\sqrt{3}+1)$ = distance from corner to surface of larger ball. But this was found to be $R(\sqrt{3}-1)$. Therefore, $r(\sqrt{3}+1) = R(\sqrt{3}-1)$. Whence, $r = .2679492\,R$. But $R = 9$ inches. Hence, $r = 2.412$ in., nearly; and the diameter of the smaller ball is about 4.824 inches.

***

(123) (*a*) Is the curved horn better than the straight one for use on the phonograph? Appearance is not taken into consideration. (*b*) If a horn is 15 inches long and $\frac{3}{8}$ of an inch in diameter at the small end, what should be the diameter of the large end? (*c*) What is the best curve to employ? (*d*) Is the divergence the same for any length? I. A. N., Medina, Ohio.

ANS.—(*a*), (*b*), (*c*), (*d*) But little theory, as far as we know, has been brought to bear as yet on the shape of phonographic reproducing horns. Most phonograph builders make their horns simply conical, with a taper of about 1 inch to the foot, but more in the larger horns. They add to the conical part a flaring mouthpiece which is intended to avoid a sharp break of the sound waves which would otherwise occur at the edge of the conical horn. From all appearances the curve of this mouthpiece is simply a circular arc in the smaller horns and a parabolic arc in the larger ones. It would appear to us that it would be worth trying to make a horn whose outlining curve would be a parabolic arc all the way through, the apex of the parabola to be located, of course at the edge of the mouthpiece.

***

(124) Give a formula for computing the rate of interest from a security investment when the price of the investment, the number of years, and the rate of interest are known. F. C., Boston, Mass.

ANS.—Let P denote the price of a bond or security that has n years to run, and bears r per cent. interest, S the face of the bond, and q the current rate of interest. Then x in the formula

$$x = \left(\frac{Sq + Sr(1+q)^n - Sr}{Pq}\right)^{\frac{1}{n}} - 1$$

is the rate of interest on the investment. When the interest is payable semi-annually, substitute for q one-half the current rate, for r one-half the rate the bond pays, and for n twice the number of years the bond runs. The x found in this case will be the semiannual rate and must be multiplied by 2 to give the rate. Example: What rate of interest will a man receive on his investment if he buys a 7-per-cent. bond, at 118, that has 12 years to run, with interest payable semiannually, and if the annual rate of interest is 5 per cent., compounded semiannually? In this case, $s = 100$; $P = 118$; and as the interest is payable semiannually, $q = .025$, $r = .035$, $n = 24$. Hence,

$$x = \left(\frac{2.5 + 3.5(1.025)^{24} - 3.5}{118 \times .025}\right)^{\frac{1}{24}} - 1.$$

By logarithms, $x = .02496$. Therefore, he receives $2 \times .02496$, or nearly 5 per cent. on his investment.

***

(125) Can you tell me where I can obtain a cord that will not stretch and that is not easily affected by the weather, suitable to use on a parallel ruling device similar to that used on the Svenson drawing table? A. M. M., Grand Ledge, Mich.

ANS.—A cord similar to that used on steam-engine indicators would, we think, be suitable for your purpose. This can be obtained from any concern dealing in steam specialties and costs in the neighborhood of 2 cents per foot.

SCIENCE AND INDUSTRY

Vol. VII | May, 1902 | No. 5

FITTING BRASSES AFTER LINING UP THE ENGINE

THE process of wearing "out of line" in an engine is a very gradual one, sometimes requiring a year or more before any difficulty is experienced and before it can be detected by means of the line and calipers.

When the main bearing is allowed to run hot, abrasion takes place to a greater or less extent and the surface of the bearing wears away much more rapidly than when it remains cool and is well lubricated. As it is the wearing away of the main bearing, principally, that throws the crank out of line, it is important that it be given special attention both in the matter of adjustment and of lubrication. Not long since an instance occurred which would seem to indicate the necessity of keeping the main bearing properly adjusted, whether it is to prevent constant heating or not. An engineer pointed with great satisfaction to a certain construction of main bearing, saying that it had been running for nearly three years without having the cap removed, and had never been, what might be called really hot during that time.

Like a great many main bearings, it was adjustable from one side only, and as wear occurred on the non-adjustable side also, the shaft kept moving over in this direction as lost motion was taken up. Of course, there was no pound because the shaft was followed up by the adjustable box on the opposite side. At the end of three years the lead on the engine was materially and rather suddenly increased, when the oscillating crankpin immediately gave trouble. The only remedy was to line up the engine, and when this was done the crank-shaft was found to be considerably out of line, but it had taken place so gradually, the adjacent parts had also worn very gradually and gave no trouble, except that plenty of lost motion had to be allowed the pins to prevent heating.

The work of lining up an engine and putting each part in its correct relation to the others requires a very short time compared to that during which it gradually gets out of line. The consequence is that when the engine is started after lining up and without refitting, the bearings and pins are liable to give fully as much trouble as when badly out of line. While this proves discouraging, to say the least, it is not unavoidable, provided proper care is taken when lining up an engine to see that the several parts fit properly in their new position.

It will be readily understood that refitting the brasses, quarter boxes, and crosshead shoes should be made a part of the work of lining up an engine, and it is easily seen how a great deal of time and annoyance may oftentimes be avoided by doing so. This will be found especially true where the engine is found to be considerably out of line, and, perhaps, has a heavy load which only tends to make matters worse. The proper time to refit the engine, that is,

the parts previously mentioned, is when putting them back into place after lining up.

First, the piston rod is centered, then the piston rings are set out, and the

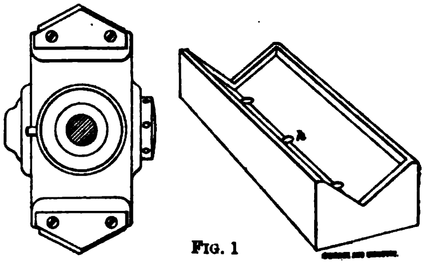


FIG. 1

crosshead lined up—these operations having been described in a previous article. If the crosshead cannot be brought into the proper position by merely adjusting the shoes vertically, then the shoes should be refitted, and this work should be done before attending to the connecting-rod, because the correct position of the wrist and crank-pin brasses cannot be obtained unless the crosshead is perfectly in line and provided with ample means for further adjustment when neccessary. After attending to the crosshead, the main bearing should receive attention, leaving the connecting-rod until the last, which will insure an accurate job throughout.

When the several boxes have become sufficiently worn to require rebabbitting, they can be babbitted while secure in the proper position on an arbor and thus be in line to start with, but in an engine which merely needs refitting, another method will frequently have to be adopted. While the following method is not by any means the only one which may be employed, it may lead an engineer to think of other methods which he may find better suited to his needs.

Suppose the crosshead shoe has worn away badly on one side, as illustrated in Fig. 1. It will be readily seen that to adjust its position vertically will avail nothing. In this case the simplest remedy will be to have the higher side planed down to match the lower one, but this cannot be profitably done unless the amount of babbit on the lower side is of sufficient thickness to permit proper adjustment afterwards, or to allow the engine to run for a considerable length of time before rebabbitting will become absolutely necessary. Such cases obviously require good judgment on the part of the engineer. If the thickness of the metal subject to wear is as thick or a trifle thicker than the amount worn away in, say, a year, then he may expect the engine to be able to run another year before rebabbitting will be neccessary.

A simple method of rebabbitting a shoe is to make a box form, as shown in Fig. 1, having raised edges, the height of which is equal to the thickness of the babbit that is to be exposed to wear. The box is made of well-seasoned hardwood, and represents a section of the guides. The old babbit is cut out of the shoe, including the small holes *a*, Fig. 2, for securing it to the shoe. The shoe is preferably warmed thoroughly in order to dispel any moisture that might be present, and is then laid face upward on the floor or bench.

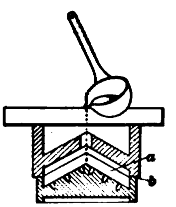


FIG. 2

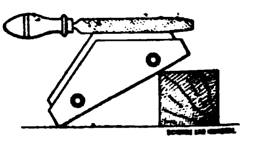


FIG. 3

The box is then laid on the shoe, with a thin layer of clay at *b* to make a tight joint. The box should be weighted down with suitable pieces of iron to prevent its being disturbed when the babbit is poured in. The babbit is

poured through the holes *h*, Fig. 1, which also serve as vents. When the shoe has been babbitted it may then be planed and scraped to fit the surface of the guides. When fitting the shoes to the guides, especially the one subjected to heavy pressure, for instance the lower one when the engine runs "over," it should be scraped to as even a bearing as possible. This is accomplished by coating a portion of the guide very lightly with red lead, then placing the shoe in the guide and sliding it back and forth a few times, when the high spots on the babbit will be found coated with the lead. These high spots are to be carefully scraped down a very little, in the manner indicated in Fig. 3, then try the shoe again, continuing this operation until practically the whole surface of the babbit is covered with the lead. Replace the shoe in the crosshead and slip the latter between the guides and raise or lower it until the piston rod is perfectly in line, in the manner described in a previous article.

When an engine is very much out of line and runs under a heavy and uneven load, the wear on the crosshead will occur more rapidly on one side than the other. This is particularly the case when a short connecting-rod is employed and with a crosshead of the locomotive design.

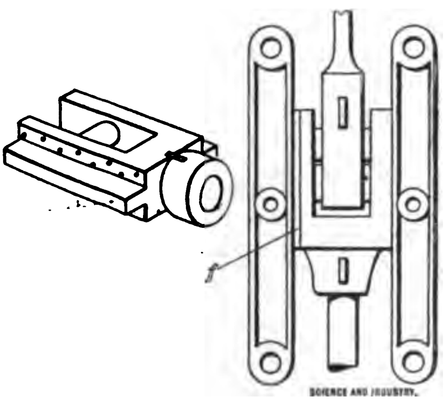


FIG. 4

The side wear on a crosshead of this pattern may, in most cases, be taken up by filing the holes in the guide bars and setting them in to the crosshead. Some engines are fitted with unusually large and heavy guide bars, and in the absence of machine tools it will be found a long and tedious job filing the holes in them sufficiently to take up the lost motion.

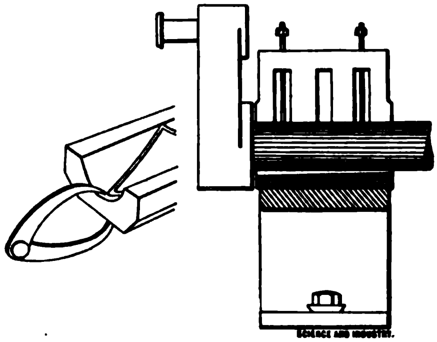


FIG. 5

When a job of this sort presents itself the simplest (and as good a way as any) will be to take out the crosshead and drill several holes at a slight angle, just above and below the wing, on the worn side, as shown in Fig. 4. Replace the crosshead and block it up tight against the top bars; stop up the ends of the space between the crosshead and the bar with clay and fill the crevice *f* with hard babbit. Turn the crosshead over end-for-end, block it up as before, and babbit the bottom part. Thin manilla paper, covered with graphite, will prevent the babbit from sticking to the guidebar.

As the pressure sidewise on the crosshead will be very slight while the engine is in line, the babbitt will last a long time, and being secured to the crosshead by means of the prejections entering and filling the drilled holes, it will give no trouble by working loose.

The main bearing comes next, and in an engine equipped with quarter boxes will require a similar operation when the shaft has been out of line

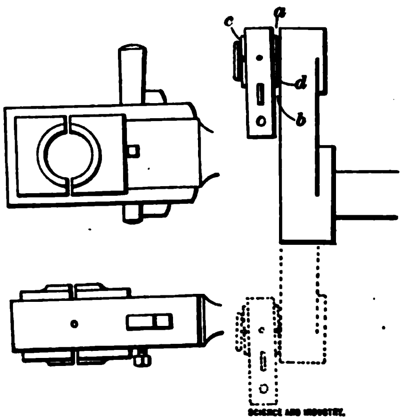


FIG. 6

vertically, and is again raised to its proper position. Fig. 5 represents an exaggerated case, but will serve to illustrate the relative position of the shaft to the bottom box after the former has been raised. The shaft will then be found to bear at one end of the box only, which may cause excessive heating. The shorter the shaft, the greater will be the space between the shaft and the box at the open end, and should this be found to be excessive it may be corrected by making the liner taper also, placing the thick end of the liner under the thin end of the box. In large engines this will be found the quicker method. The exact taper to which the liner must be planed is obtained by calipering the ends of the box as shown in the same figure; the difference in the thickness of the box at the ends will be the amount to be taken from the tapered side of the liner, the bottom of the liner must, of course, be parallel to the shaft. The quarter boxes may be shifted as required by the adjusting screws.

Suppose we have a connecting-rod with strap ends as shown in Fig. 6. If the shaft has been much out of line, when the strap is put onto the pin and the key driven home, or the wedge raised up tight as the case may be, the strap will stand at an angle to the crank at certain points in the revolution of the pin as shown in the same figure.

Now it will be understood that, if the strap should be connected to the rod and then put onto the pin, the brasses would have a bearing about as shown in Fig. 7. It is unnecessary to tell an engineer that the brasses would run "red hot" in less than an hour when in this position. You have probably noticed that the brasses cannot be keyed up nearly so tight in an engine that is out of line. The cause of this is not hard to find. When a shaft is out of line both vertically and horizontally the effect upon the brasses is practically the same as would be produced by an oscillating pin, that is, at certain points in the revolution of the pin the stress would be sidewise on the connecting-rod, while at others it would have a tendency to rotate the crosshead in the guides, and as these tendencies cannot be accommodated

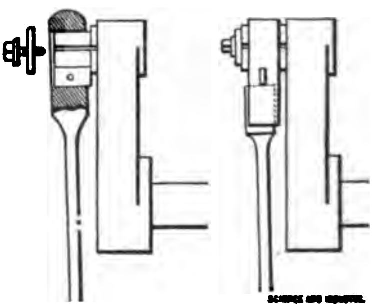


FIG. 7

owing to the stiffness of the rod, the brasses are severely twisted and tend to bear very hard on only a portion of their surface. The result is, excessive

pressure is brought to bear on a very limited bearing surface, and heating is the natural and inevitable result.

The strap must be straightened, that is, its center line must correspond to the center line of the connecting-rod. This may be accomplished, in the absence of the use of machine tools, by first cleaning the surface of the pin and brasses of oil and then placing the strap and brasses on the crank or wrist pin; drive the key so hard that the strap can just be turned without using a lever or wrench. Take a pair of inside calipers and get the distances *a* and *b*, Fig. 6, which will not be found the same, for the strap will probably have changed its position relative to the crank when turned over. The brasses are to be marked at *c* and *d*, Figs. 6 and 7, which represent the ends at which the high places occur, that is, in order to straighten the strap some of the metal in the brasses must be removed at the ends *c* and *d* of the wearing surfaces of each brass.

Before attempting to scrape the brasses to a fit, the oil grooves should be cut in the surface of the brass, or deepened, so as to permit the oil to flow freely through them, and the edges of the brass *r*, Figs. 8 and 9, beveled off for about an inch each side of the entrance to the oil grooves in

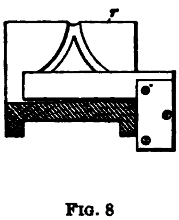


Fig. 8

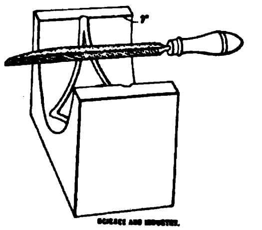


Fig. 9

order to remove the sharp edge, which, if allowed to remain, will tend to strip the oil off the pin and not only cause unneccessary waste of oil, but endanger the proper degree of lubrication. One form of chisel for cutting oil grooves is shown in Fig. 10. The depth of cut is regulated by raising or lower-

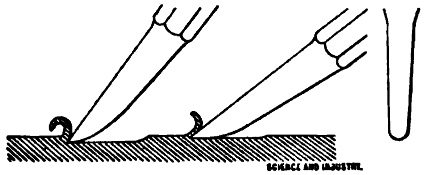


Fig. 10

ing the hand, thus changing the angle of the tool relative to the surface of the brass. Now remove the strap and brasses and place a try-square on the brass as shown in Fig. 8. It will be found to be out of square considerably. The brasses must then be scraped until the square will just "touch" from one side of the brass to the other. When this is accomplished, put the brasses in the strap and place them on the pin; key up tight again and caliper the distances *a* and *b*, which should now be very nearly, if not exactly, the same. If they are not, remove the strap and scrape off a very little more and again replace it on the pin. Before connecting to the rod, turn the strap around on the pin several times, and remove it from the pin. The high spots, if there are any, and it is well to be sure there are none, may then be seen and may be reduced by the careful use of the scraper in the manner indicated in Fig. 9.

A half-round file ground smooth, with nicely sharpened edges, furnishes about as good a scraper as any; the slightly curved edges permitting the scraper to be turned at a slight angle when working, which produces a shearing action that is difficult to obtain with a straight scraper on concave surfaces.

When the strap is now connected to the rod the brasses will be in line and

will have an even bearing on the pin. The wristpin brasses should now be screwed up tight, so that the connecting-rod can just be turned on it. Raise

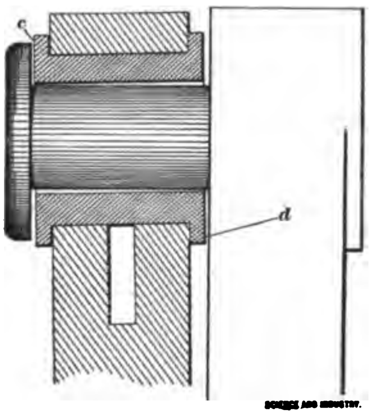


FIG. 11

the crank end of the rod and slip on the crankpin strap. If the wristpin brasses need the same treatment, which will be found to be the case unless the connecting-rod is a very long one, the crank end of the rod will not fit squarely into the strap when the brasses are tightly keyed to the crankpin, or, when a solid end or solid strap is employed the crankpin brasses will not be flush with the rod, as shown in Fig. 11. When these conditions exist, the wristpin brasses must also be squared up by scraping.

The keying up of the brasses at either end of the rod will have no tendency to throw the rod out of line, when the brasses are fitted squarely to the pins. The free end of the connecting-rod must, of course, be supported in such a manner as to be free to move sidewise when the brasses at the opposite end are keyed up tight. If this work is carefully done, the rod and brasses when connected up will occupy the same position as regards alignment that they did when new, and they will give no trouble when the lost motion is properly adjusted and the pins are sufficiently lubricated.

When the connecting-rod has been connected up, have the crank turned first to one dead center and then to the other, and measure the distance between the line on the crosshead and the one on the guide. If the engine is of fair size, say with a cylinder of 16 inches or more in diameter, this distance will be about a $\frac{1}{4}$ inch when the connecting-rod is properly adjusted so that if sufficient wear has occurred to reduce the clearance as much as $\frac{1}{16}$ or $\frac{3}{32}$ inch, the remaining space between the piston and the cylinder head will be rather too small for safety, that is, for any considerable length of time, and the connecting-rod should be adjusted to the proper length so that the clearance

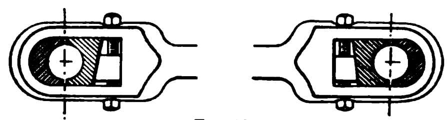


FIG. 12

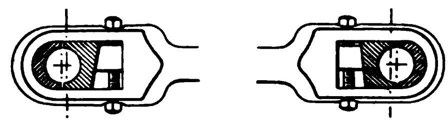


FIG. 13

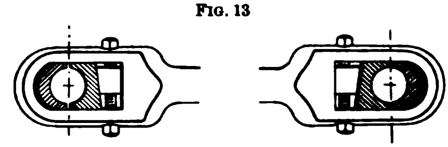


FIG. 14

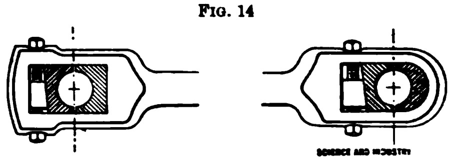


FIG. 15

will be the same at both ends of the stroke.

A large number and possibly the majority of connecting-rods have the wedges inside or between the pins as shown in Fig. 12. As a general thing the end or outside brass at the crankpin

will wear faster than the corresponding brass at the wristpin end of the rod, which is due to the greater movement of the crankpin, being similar to a shaft in a bearing, while at the wristpin the motion is due merely to a slight oscillation of the rod. In this case, the wedge at the crank end will be drawn up to the upper strap before the one at the wristpin has got half way. The length of the rod, which is measured between the center of the crank and wristpins, will have been increased as shown in Fig. 13, and this will tend to decrease the clearance at the end of the stroke nearest the cylinder. It is apparent that the length of the rod must be decreased in order to draw the crosshead farther away from the cylinder end of the guides. This is accomplished by inserting a liner behind the outside or end brass so as to take up the same amount that has been worn away. The inserted liner is shown in Fig. 14. It is well to place the crank nearly on the dead center nearest the cylinder. Then loosen the adjusting screws and lower the wedge to the bottom of the strap, or slot, if it is a solid end rod as shown. Now have the crank placed on the dead center, when the end brass may be moved in against the crankpin leaving a space to receive the liner. The latter may be of sheet brass or sheet steel the brass usually being preferable as it is more readily worked into the proper form. The liner should fit the brass and the slot in the rod snugly so as to avoid any tendency to work back and forth when the pressure is alternately applied and removed. The thickness of the liner may be equal to the amount the rod is to be shortened. Put in the liner and draw up the wedge snugly then slacken it slightly. Measure the distance between the line on the crosshead and on the guide. It may be found that the clearance is now slightly greater at the head end due, perhaps, to the liner being a trifle thicker than need be, but this need not be reduced if the difference is slight, say $\frac{1}{32}$ or $\frac{3}{64}$ inch, because the rod is constantly lengthening while the engine is in motion and the clearance will very soon equalize itself. If, however, the difference is sufficient to require equalizing it may be done by removing the liner behind the outside brass at the wristpin end.

Some engine builders make the outside brass at the crank end and the inside brass at the wrist end, adjustable, as shown in Fig. 15. This tends to preserve the original length of the rod to a greater extent, but even with this arrangement the striking points should be kept plainly marked on the guides, because with the latter construction the tendency is to shorten the rod as wear occurs, which is due to the more rapid wear of the stationary brass at the crank end. This, it will be seen, tends to bring the pin centers nearer together and consequently decreases the clearance as indicated by the distance between the lines, this time at the crank end of the guides.

SOME AVERAGES OF ELECTRIC LIGHT COSTS AND CHARGES

(*Electrical Review*)

THE SUBJECT of the cost of fuel and the other necessities for the production of electric light, and the charges made for electrical supply by plants in various parts of the country, is one that appears not to have received any great amount of attention or investigation. Recently the Electrical Review sent out a large number of enquiries to representative electric-light stations in all the states of the United States requesting information concerning—

1. The price of coal.
2. Whether or not water-power is used in the production of electric current.
3. Whether current is sold on the meter or contract basis.
4. The base rate of charge per kilowatt-hour and the minimum rate of charge per kilowatt-hour for large customers.

Responses to these enquiries have been received from a sufficient number of stations to permit the preparation of averages which are believed to be fairly accurate and representative. The stations represented in these averages are situated in all parts of the United States from Maine to California, and from Florida to Oregon. On account of the private nature of some of the figures given it is not possible to give the names of the stations represented in these averages, but all of them are representative stations of average size, operated as nearly as could be determined upon the lines of good average practice. The results are of great interest.

1. Concerning the price of fuel: The highest price paid for coal by the stations replying is $6 per ton, and the lowest price $1 per ton, the latter representing slack coal, and the former "run of mine." The average price of coal paid by stations representing all but a few states is $2.96 per ton, delivered at the plants.

2. Concerning water-power: Twenty per cent. of the stations listed use water-power either wholly or in part for power production.

AVERAGES OF FIGURES OF COAL COST AND POWER CHARGES RECEIVED FROM REPRESENTATIVE ELECTRIC LIGHTING STATIONS

	Lowest Cost of Coal	Highest Cost of Coal	Average Cost of Coal	Average Base Charge for Power	Average Minimum Charge for Power	Per Cent. Water Power
Eastern States......	$2.60	$4.90	$4.05	14 cents.	6.05 cents.	17.0
Middle States......	1.00	6.00	2.29	12 cents.	5.08 cents.	9.2
Southern States...	1.33	3.50	2.42	11.5 cents.	5.50 cents.	24.0
Western States....	1.80	5.00	3.68	7.5 cents.	4.00 cents.	29.8
All States..........	$1.00	$6.00	$2.96	12.3 cents.	5.1 cents.	20.0

3. Basis of sale of power: Nine per cent. of the stations adhere to the old contract basis. Four per cent. use both the contract and meter basis, while 87 per cent. use the meter basis entirely and exclusively in determining their charges for current supply.

4. The basis of charge: This is in many respects the most interesting of the figures obtained. The highest basic rate of charge made anywhere is 20 cents per kilowatt-hour, this rate being

confined to a few stations in the eastern states. The lowest minimum rate charged is 1 cent per kilowatt-hour, this rate referring to a water-power plant operated in connection with a long transmission line and supplying customers with power for general purposes, including street railways. The average base charge per kilowatt-hour through the United States is 12.3 cents, while the average minimum charge to large consumers is 5.1 cents.

If we might assume that the price of fuel is a fair indication of a reasonable basis of charge, it will be seen that the rate per kilowatt-hour figures out at about 4 per cent. of the cost of a ton of coal. In other words, the average efficiency of conversion of coal into power is at the rate of 1 ton for 20 kilowatt-hours sold. On the same basis, the average minimum is 1.7 of the cost of coal, representing an apparent maximum efficiency of conversion of 1 ton of coal into 59 kilowatt-hours. This assumption, however, does not seem to be entirely warranted, since an examination of the data received shows that there is very little apparent connection between the price paid for fuel and the amount charged for power. For example, a station paying $5 for coal has a basis rate of 10 cents, with a minimum of 2 cents; whereas another station paying only $1 for coal has a basis rate of 15 cents and a minimum charge of 5 cents. Perhaps all that may be definitely claimed as shown by these figures is that other elements than the cost of fuel are the determing factors in the output cost of electric current, or else that the subject has never received that scientific investigation which is its due.

In the United States we are in a position curiously contrasted with that in which English central stations find themselves. In that country a legal requirement forces the publication of the figures of cost and charge, the former being analyzed very carefully for all public supply plants. The most immediate result of this publicity has been the close and accurate study of the costs of electric supply and the understanding on the part of station managers and the shareholders in such enterprises of the various elements entering this business. A large part of the stations in that country are earning satisfactory dividends upon the investment they represent.

Summing up the results as given above the table on the preceeding page was constructed.

LONGEST POWER TRANSMISSION SYSTEM

IT MAY be interesting to readers of SCIENCE AND INDUSTRY to know that the longest power transmission system now in operation in the world is in California.

The Standard Electric Transmission Company transmits power 215 miles from the Blue Lakes power house via Oakland and around the southern end of San Francisco up to Redwood, Cal.

It is stated that the overall efficiency of this transmission, measured to the receiving step-down transformers at the terminus, was as high at full load as 80 per cent. The power is utilized for lighting, electric railway, and general power purposes, and a very considerable portion of it is used also in the operation of shovels and other tools used in placer mining in the gravel drifts near the power houses. In both of these plants the hydraulic equipment consists of high-head, high-velocity impulse wheels, and each plant has a capacity of about 10,000 kilowatts.

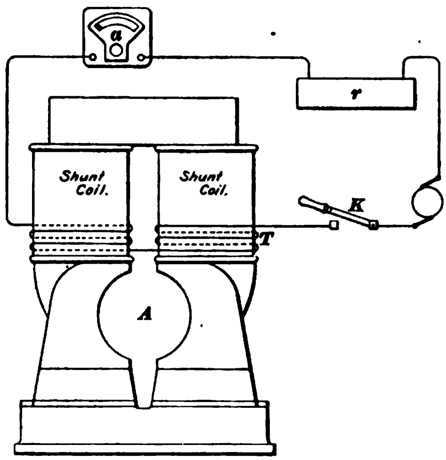
COMPOUNDING A SHUNT-WOUND DYNAMO

SHUNT-WOUND dynamos were at one time used much more generally than they are now, so that in stations where new machines have been added from time to time, it is common to find a number of old shunt machines working alongside the newer compound-wound ones. Compound machines are more desirable than shunt, because they automatically increase their voltage as the load comes on, and thus keep up the voltage at the distant end of the line without it being necessary for the switchboard attendant to continually shift the rheostat handles. With the shunt machines, the field resistance has to be cut out as the load increases in order to keep up the voltage. In most cases it is desirable to run these old machines in parallel with the newer ones, but it is not possible to do so because a shunt machine will not run in parallel with a compound-wound one. The reason for this is not hard to see, for suppose the machines were running in parallel and each taking its proper share of the load; if the load on the compound-wound machine should increase, its voltage would increase and it would soon be generating a higher voltage than the shunt machine whose voltage becomes lower with increase in load. In order to run the machines in multiple, the shunt machine should be provided with series coils.

The question then arises, how are we to determine the number of turns and size of wire to put on these coils? We will assume that the windings of the shunt machine are not known; that is, we do not know the number of turns or size of wire on either the armature or field, so that the correct number of turns will have to be determined wholly by experiment. In order to fix ideas we will assume that we wish to compound an Edison bipolar machine having the style of field shown in the figure. The machine has a full load current output of 200 amperes, and we wish it to generate 110 volts at no load and 125 volts at full load. In other words, the machine is to be overcompounded so as to give a rise in voltage of 15 volts from no load to full load. Wind a number of turns T of any convenient size wire on the fields as shown and count the turns as they are wound on. These may be wound on over the shunt coils and no particular pains need be taken to get them on neatly, because they are only temporary and have to be taken off again. No. 6, 8, or 10 wire will answer very well, but the smaller the wire used the more turns must be put on because the temporary coils must supply as many ampere turns as the permanent coils to be put on later. Wind these temporary coils so that the current will circulate in opposite directions around the two limbs of the magnet. In series with these coils connect an ammeter which will read as high as the current that the temporary coils will safely carry. Also connect in the circuit a water rheostat or any kind of adjustable resistance that will handle the current. Connect the terminals of this temporary coil circuit to another dynamo or any other source of steady current. Run the dynamo A up to speed and adjust the voltage to 110, with A's main switch open so that the machine carries no load. Switch K should also be open. A is now running as a plain shunt machine on no load, and is generating an E. M. F. of 110 volts. Now apply a load to A; we will suppose that a full load of 200 amperes is put

on A by means of a water rheostat or by combining a water rheostat with the regular load of the machine. Of course A's voltage will fall off as soon as the load is applied, because the field rheostat is not moved, and A is yet a plain shunt machine. Close switch K and adjust the water rheostat r until A's voltmeter shows the required full-load voltage of 125 volts. Note the current in a that is required to bring A's voltage up to 125. When this has been done we have enough data from which to obtain the series winding, and K may be opened.

Suppose the temporary coils consisted of 25 turns on each leg of the magnet, or 50 turns in all, and that it required a current of 45 amperes, as indicated by a, to bring the pressure up to 125. It is evident, then, that there must be $50 \times 45 = 2250$ ampere turns added to the ampere turns of the shunt coils to bring up the voltage, and this is the number of ampere turns to be supplied by the permanent series coils to be put on the machine.



The temporary coils are now removed preparatory to winding on the permanent coils. The full-load current of the machine (200 amperes) will pass through these coils if the two coils are connected in series, hence the total number of turns required would be $\frac{2250}{200} = 11.25$, or say 12 turns, to make an even number. Six of these would be wound on each leg, and the conductor would have to be large enough to carry 200 amperes. Or we might connect the two series coils in parallel and put 12 turns on each, in which case each coil would carry only 100 amperes and would require a much smaller wire, which would be easier to wind. However, it is better, if possible, to always connect series coils on dynamos in series rather than in parallel even if they are a little harder to wind, because, with the series arrangement, the current in all the series coils is bound to be the same, whereas if they are connected in multiple their currents may not be the same because their resistances may not be exactly alike. It is a comparatively easy matter to make a number of series coils that will have the same number of turns, but it is not by any means so easy to make them have the same resistance. However, with a bipolar machine a slight inequality of the currents in the series coils does no particular harm. It is only in multipolar machines that it becomes desirable to keep the magnetizing force of all the coils as nearly alike as possible. We will assume in this case that the two coils are to be connected in series so that there will be six turns on each leg. For a coil of this kind, a cross-section of 800 circular mils per ampere should be sufficient, because the turns will be well exposed to the air and the current through them will seldom remain long at the full load of 200 amperes. Making the above allowance, the cross-section of the conductor would be $800 \times 200 = 160{,}000$ circular mils. By consulting a wire table we find that a No. 000 B. & S. wire

has a cross-section of 167,805 circular mils, so that this wire would answer.

A round wire neatly wound on over the shunt coils makes a well-appearing job. The writer knows of a number of shunt-wound machines that were compounded by winding over the coils a number of turns of insulated $\frac{5}{8}$-inch round copper. Of course, such material is not the easiest in the world to get into place, but after it is once on it looks very well indeed. A very neat job can also be done with stranded copper cable. Some persons prefer to use copper strip for the series coils because it is easier to wind than heavy wire and it is very easily insulated by winding a layer of insulating material between the layers of strip. About 1,500 amperes per square inch cross-section of strip is a fair allowance for this class of work.

In making the above estimate of the ampere turns required for the series coils, it will be noticed that the machine *A* was run at its full load. Machine *A* might be run at half load (100 amperes) and the ampere turns noted to bring the pressure up to $110 \times \frac{15}{2} = 117.5$ volts. The trouble is, however, that the ampere turns required to bring the voltage up the total of 15 volts might be considerably more then twice the amount required to bring it up 7.5 volts. This is because the field magnet frame may be nearly saturated and an increase in current may not be accompanied by a corresponding increase in magnetism or voltage. Running at full load is, therefore, the safest way to get a close idea as to the number of series turns required. In compounding a machine, it is just as well to put on a few series turns over and above the number calculated, because the compounding can be accurately adjusted afterwards by connecting a low resistance shunt across the terminals of the series coils.

MERCADIER MULTIPLEX TELEGRAPHY

A SERIES of very interesting experiments has recently been performed between Paris and Bordeaux, France, with the Mercadier multiplex telegraph system, originated by Ernest Mercadier. It is stated that no difficulty whatever was found in transmitting over the same wire 16 simultaneous messages, which were received by an equal number of operators without the least confusion. During the experiments 1,300 dispatches, averaging 20 words each, were sent between Paris and Bordeaux in relays of 16 at a time. The inventor says that his system is based on the principle of sending undulatory currents over the wire instead of continuous currents. Differently tuned transmitters and receivers are used, each receiver responding only to a similarly tuned transmitter. Skeptical views as to the practicability of the system are held by many of the prominent telegraph engineers of this country. It is thought by many that there would be much trouble in the operation of such a system under constantly varying atmospheric conditions. The principle of this multiplex telegraph system was briefly explained in SCIENCE AND INDUSTRY for July, 1901.

USEFUL FORMULAS—IV

BY JOSEPH E. LEWIS, S. B.

$$H.P. = \frac{Plan}{33{,}000}$$

WORK is force through space, to put it in a rough way. To explain: Force is an effort to overcome resistance, but unless the resistance is actually overcome no work is done. A man may try for hours to lift a 1-ton weight without the aid of machinery and exert all the force of which he is capable but he will not do a particle of work, although he may become very tired. If, however, he were to rig up a chain hoist he could raise the weight with ease and then he would be doing work. He would be exerting force through space, and every time he raised the ton weight 1 foot he would perform 2,000 foot-pounds of work.

A foot-pound is the unit of measure of work and is that amount of work which is done in raising 1 pound through a vertical height of 1 foot against the force of gravity. Force is a difficult thing to define; it is the starting point in mechanics. About all that we can say of force is that it *is* force, and then we go ahead and define work and horsepower, etc. in terms of it. The force of gravity is the most common natural phenomena of our daily experience, and yet we are as far from defining its real nature as we were one hundred years ago. We know how it acts; we are able to use it for our own ends; we know the mathematical laws of its action; but like life itself, its real nature eludes us in the final analysis.

Work, then, is force through space. We do 1 foot-pound of work in lifting 1 pound 1 foot. Now, if we release it the pound weight does 1 foot-pound of work in falling back again to the ground. Energy in mechanics is nearly synonymous with work. We might make a distinction and say that work is done at the expense of energy; that is, we might call energy the power of doing work. A pound supported at an elevation of 1 foot has the power of doing work in falling to the ground; it has potential energy. When it falls it does work and while falling it has kinetic, or active, energy which expends itself in actually doing the work.

Now, there is a scientific theory known as the "Conservation of Energy" which holds that the sum total of all the energy in the universe never changes. That is to say, when the pound falls to the ground the mechanical energy expended in doing the work is not lost, but is changed into some other form of energy, as heat, for instance. All mechanical energy is finally changed into heat, and likewise, heat is the ultimate source of all mechanical energy. The sun, being the source of all our available heat energy, is consequently the source of all mechanical energy. The heat energy stored up in the coal through the long ages of its formation came from no other source than the sun; and when we burn the coal in our furnace we are liberating the sun's heat, stored up so long ago, and using it in heating our buildings or generating steam for our power plants. Thus the heat of the sun is transformed into mechanical energy in our engines through the medium of steam generated in the boiler.

The same is true regarding the mechanical energy which we derive from

water-power, and here the transformation of the sun's heat into mechanical energy is even more apparent and readily understood since the process is going on continuously before our very eyes. We see the rains descend from heaven replenishing the streams whose waters we dam up to operate our waterwheels. If we but take account now of the increasing evaporation of water from the earth's surface by the sun's heat to supply the clouds with rain, the cycle is complete. The sun is ever lifting the water in minute particles from the surface of the sea and of the land, and thus is the source of all our water-power.

And likewise all mechanical energy at last finds its way back to its original form, namely, heat, but more widely diffused and at a lower temperature. The energy of the mill engine is changed into heat by friction in the bearings and working parts of itself and of the machinery which it drives. The energy of the electric power-house engine is transformed largely into electricity, which is in turn changed into heat and light, or back again into mechanical energy, as in the motors of street cars, and finally into heat again, as in the rolling friction of the cars themselves. We might trace these transformations of energy almost endlessly, and we should find the subject one of great interest, but it is our present purpose to carry the discussion only so far as will help in understanding the nature and the measurement of work.

A foot-pound, then, is the work done in raising 1 pound 1 foot against the force of gravity without reference to the time it takes to raise it. But in measuring work time is an important consideration. So many foot-pounds per minute would be a convenient unit of work to use in measuring the amount being done. Such a unit has been invented. It is called a horsepower (H. P.), and it consists of 33,000 foot-pounds per minute. To raise 33,000 pounds 1 foot in 1 minute constitutes 1 horsepower. To do the same amount of work or expend energy at the same rate in any other way than lifting weights would amount to the same thing. For instance, if there is a total pressure of 33,000 pounds back of a piston and we push it through a space of 1 foot in 1 minute we are developing 1 horsepower (neglecting friction).

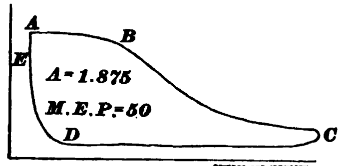
Right here a distinction should be made. If a man carries a 100-pound weight on his shoulder 100 feet he has not performed 10,000 foot-pounds of work. He has actually performed 500 foot-pounds in lifting the weight 5 feet. In addition to this he has performed that amount of work necessary to propel himself and the weight 100 feet. Just how much work this represents is difficult to say. Again, if a freight car weighing 33,000 pounds is pulled along at the rate of 100 feet per minute we are not necessarily developing 100 horsepower. The work actually done on a level track is only that necessary to overcome the inertia and rolling friction of the car. The work done by a locomotive in pulling a train is not found by multiplying the weight of the train by the number of feet per minute that it travels. It may be actually found by multiplying the pull exerted by the engine in pounds by the number of feet traveled per minute.

Let us consider now the computation of the horsepower developed in the cylinder of a steam engine. To make the case simple imagine a cylinder 12 inches in diameter, the piston having a stroke of 2 feet. Suppose the average pressure back of the piston to

be 50 pounds per square inch. This average pressure is called the "mean effective pressure," or M. E. P. The way to find it will be discussed later. Now let the engine make 125 revolutions per minute. The piston then makes 250 strokes 2 feet long each minute; that is to say, it travels 500 feet per minute. This is called the "piston speed." The area of the piston is $\pi R^2 = 3.142 \times 6 \times 6 = 113$ square inches, very nearly. Since the pressure per square inch is 50 pounds the total pressure on the piston is 5,650 pounds. As the engine runs along at a constant speed this pressure is just balanced by the resistance of the load on the engine, so that the work being done by the steam will be found by multiplying the pressure on the piston by the number of feet traveled by the piston in 1 minute, $500 \times 5{,}650 = 2{,}825{,}000$ foot-pounds per minute. Since 33,000 foot-pounds equal 1 H. P., the engine is developing $\frac{2{,}825{,}000}{33{,}000} = 85.6$ H. P. This is the indicated horsepower I. H. P. The brake horsepower, or the work delivered by the engine to the main shaft, will be somewhat less than this.

Now let us examine the formula for figuring this result, H. P. $= \frac{Plan}{33{,}000}$ where $P =$ the mean effective pressure in pounds per square inch, $l =$ the length of the stroke in feet, $a =$ the piston area in square inches, $n =$ the number of single strokes of the piston per minute, or twice the number of revolutions of the engine. Applying this formula to the case above, we have, H. P. $= \frac{50 \times 2 \times 113 \times 250}{33{,}000} = 85.6$. l, a, and n, may be readily found in almost any case, but P is somewhat more difficult to obtain. The only accurate way to find it is by using the indicator and the planimeter.

Referring to the accompanying figure, suppose this to be a card, reduced to one-half size, from the head end of the engine under discussion. Let the scale of the spring be 80, which means that every inch of vertical height of the card represents a pressure of 80 pounds to the square inch. The height of the steam line is $1\frac{1}{8}$ inches showing an initial pressure of about 90 pounds. The length of the card is 3 inches. Its area found by the planimeter, or in the manner described in last month's article on "Areas and Volumes," is 1.875 square inches. Divide this area by the length 3, and



we have the average height of the card, which equals 0.625 inches. This average height represents the average or mean effective pressure, which is $0.625 \times 80 = 50$ pounds. This is the M. E. P. for the head end. For the sake of simplicity we have assumed it to be the same for the crank end, so that the M. E. P. to use in the formula is 50.

Now, in actual practice, it rarely happens that the M. E. P. is the same for both ends, and furthermore, the area of the crank end of the piston is reduced by the piston rod. It is therefore necessary to find the H. P. of the head end and of the crank end separately, in order to produce an accurate result. Suppose the M. E. P. for the head end to be 47.3, and for the crank end 45.7. $l = 2$ for each end. $a = 113.11$ for the head end, and assuming the piston rod to be 2 inches in diameter, $a = 113.11 - 3.14 =$

109.97, or 110 square inches for the crank end. $n = 125$ for each end. Then the horsepower is found as follows: for the head end,

$$\text{H.P.} = \frac{47.3 \times 2 \times 113 \times 125}{33{,}000} = 40.5,$$

and for the crank end,

$$\text{H.P.} = \frac{45.7 \times 2 \times 110 \times 125}{33{,}000} = 38.1.$$

The total H. P. of the engine is then $40.5 + 38.1 = 78.6$.

This is the indicated horsepower, or I. H. P., and while this is the work done by the steam, it is somewhat greater than the brake H. P., which is the work delivered by the engine to the main belt. The brake H. P. is the indicated H. P. minus frictional losses in the bearings and working parts of the engine itself. Prof. Thurston's tests on a number of different styles of engines indicate that the friction of any engine is practically constant under all loads. In one test the I. H. P. varied from 7.41 to 57.5, and the friction H. P. varied irregularly between 2 and 4, the variation being independent of the road. With 50 H. P. on the brake the I. H. P. was 52.6, the friction being only 2.6 H. P., or about 5 per cent. It will be seen that since the friction is nearly constant while the load varies, it may often be a much larger percentage of the total H. P., especially when running with small load.

THE SCIENCE OF STEAM MAKING

JOHN C. PARKER

(A Paper read before the Engineers' Club, of Philadelphia)

IN A historical sketch of the steam engine by Rankine (p. xix) occurs this passage: "In the history of mechanical art, two modes of progress may be distinguished—the empirical and the scientific; not the practical and the theoretic, for that distinction is fallacious; all real progress in mechanical art, whether theoretical or not, must be practical. The true distinction is this: that the empirical mode of progress is purely and simply practical; the scientific mode of progress is at once practical and theoretic. . . . Up to the period when Smeaton perfected the atmospheric engine, the progress of the 'fire engine,' as the steam engine was then called, had been merely empirical; and in everything that depended on principle, the steam engine of that period was a most rude, wasteful, and inefficient machine."

The wastefulness of the steam engine was the prime cause of its scientific development, whereas the boiler presented no such economic problems. The comparatively high economic performance of the boiler under adverse conditions has retarded scientific development, and its progress has been entirely empirical.

To make the steam engine operative certain well-defined principles must be followed. It is not so with the boiler; any kind of an apparatus, no matter how oddly it may be constructed, will produce steam nearly as efficiently as the most approved design. It has been so easy to make steam that there has been little incentive toward scientific treatment of the problem.

The physical conditions involved in the scientific generation of steam can be graphically shown by a diagram (Fig. 1).

The vertical scale represents temperatures above 0° F.; 2,500° F. is

taken to indicate the initial temperature of combustion, and the curve illustrates the fall in temperature of the gases in their passage to the flue, where they escape at 600° F. The line at 362° F. represents the boiler temperature due to the pressure (in this case 143 pounds), and the difference in temperature between the boiler and the flue gases is thus 238°.

Since, owing to rigidity of construction, present practice aims to secure equal temperature throughout the boiler, the line at 362° will be straight, and, since there can be no conduction of heat from a lower to a higher temperature, it would be impossible to reduce the temperature of the gases below 362°.

But suppose we are not tied down to a rigid structure, and are free to have the different parts of the apparatus at different temperatures without affecting each other. We will cause the feedwater to flow in the opposite direction to the gases. If the feed comes from a heater at 212° F., that end of the evaporation line will be inclined (slightly curved) from the starting point at 212° F. until 362° is reached, when it will be horizontal to the point at which superheating begins, where it will again be inclined, but very much more toward the vertical, both on account of the low specific heat of steam and the great difference in temperature.

With the same difference in temperature between the flue gases and the water as before (238°), the flue temperature would be reduced to 450°, which amounts to a saving of 12.4 per cent. If the feedwater happened to be at 62°, the flue temperature would be reduced to 300° (with the same difference), which would mean a saving of 23.39 per cent. In this case the temperature of the gases is lower than the temperature of the steam, and this illustrates how heat may be transmitted from a lower to a higher temperature by convection.

It will be observed that superheat could not be added under these conditions at the cool end, but it might be very easily at the other end, with the result of increasing the initial temperature of combustion, and so adding to the economy at both ends.

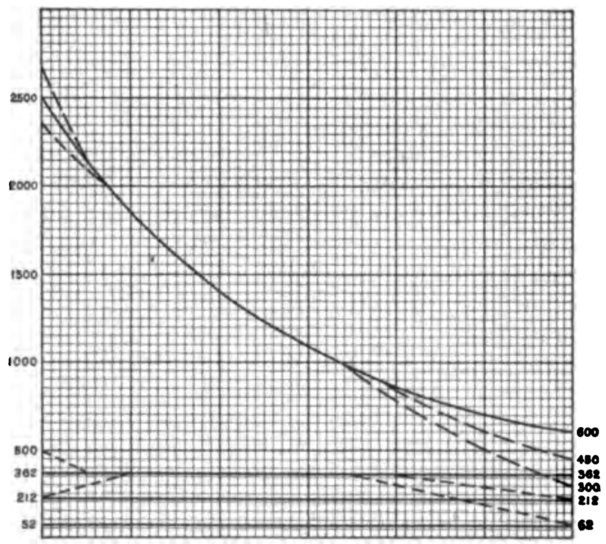


Fig. 1

If the water came in at the hot end of the diagram the rise in temperature would be more rapid, as indicated by the dotted line, but the initial temperature of combustion would be lowered as shown.

It must be evident that to secure the maximum transmission of heat from the gases to the water they must flow in opposite directions, and evaporation

must be completed in a single circuit. If any water is recirculated after being raised to the boiling point, it must necessarily reduce the economy by raising the feed temperature and so reducing its capacity for absorbing the heat of the gases; furthermore, superheating would be impossible and the initial temperature of combustion would be lowered.

It is also plain that, while the transmission of heat is as the square of the difference in temperature, the difference will not be maintained except in proportion to the rapidity of the flow which must be impelled by a constant force.

The diagram demonstrates that the functions of the economizer, the boiler, and the superheater are but separated parts of a single progressive operation which can be more perfectly accomplished in one apparatus.

This is in effect an application of the regenerative process first applied to the air engine about the year 1816 by the Rev. Dr. Stirling, and subsequently improved and modified by Mr. James Stirling, Captain Ericsson, Mr. Siemens, and others. Attempts were made to apply it to steam generating in France by Belleville in 1856, and in America by Herreshoff about 1878. Mr. Yarrow has made an application of it to his type of boiler quite recently, and he presented an excellent paper on the subject before the British Institute of Naval Architects at the March meeting, 1898.

Belleville and Herreshoff both started on the basis that the flow of the water and gases should be opposite, and evaporation progressively secured in a coil. Both used a pump to maintain the flow, and to that fact their failure may be ascribed.

Belleville assumed that the trouble was due to there being no water in the tubes in direct contact with the flames, and so abandoned his correct principle. He resorted to the common practice of supplying the water to the hot end of the coil, but his troubles were not ended. He made no material progress until he discarded the pump and adopted a gravity circulation. It took him twenty-three years to develop an operative boiler, and that he did so finally, on an incorrect principle, is a remarkable tribute to his personality.

After twenty-two years of use and six years trial in the British navy, which has now about 1,000,000 horsepower, the Belleville boiler has just been condemned by a Parliamentary commission, composed of the most experienced engineers in all Great Britain.

We now have the spectacle of the best engineering talent in the British Empire making a series of exhaustive tests of the *most tried* boilers to take the place of the Belleville.

If we draw any significance from this, it means that twenty years, or any number of years use, will not make a good boiler of a bad one. It means that none of the boilers come up to the requirements, and that there is very little difference between them. It means that, so far as the boiler question is concerned, they are farther at sea than any of their ships, else why should they proceed to test boilers which have been in use a great many years, and the qualities of which are as well known as the Belleville? The fact is that after two centuries of empirical progress we find ourselves at the opening of the twentieth century with the steam generating problem still before us. The "boiler question" has been peculiarly acute during the past decade, particularly in Great Britain, and it would seem as if important results were to be expected, in view of the amount of attention which is being given to the subject.

So far as principle goes, we are making steam today by the same process adopted by Hero, of Alexandria, 2,000 years ago—i. e., we boil water in large quantities and draw off the steam from the same chamber—both very improper practices. We may have stuck some flues through the water chamber to increase the heating surface, or perhaps we have divided up the water space into a mess of tubes. but so far as principle goes, Hero was not one whit behind us in the art of steam making.

While pressures were low the boiler was reasonably satisfactory; but when the pressure rose above the atmosphere, a new condition was introduced: the pressure was no longer constant and explosions began to be known. As weakness developed it was met at the visible point, and a stay was inserted, a tube beaded over, or a furnace corrugated. Safety became the fundamental idea in boiler design to the exclusion of correct principles, with the result that neither has been attained. The comparative safety of the boiler today is more of a tribute to the steel maker than to the designer.

Only one important conclusion has been reached in the steam-making problem in a century of remarkable scientific progress in other directions. The idea has become almost universal that a free circulation of the water is essential to the safe generation of steam, and that idea is absolutely incorrect.

The primordial condition for the safe generation of steam is a *constant flow* of the water and steam in one direction. This condition has never been fulfilled. The constancy of the flow is effected in two ways: by forcing the fire until the water is driven in the wrong direction, and by the lifting effect due to falling pressures, which produces a like result.

While the lifting effect due to falling pressures has been well known, the extent of its influence on the motion of the water and steam has never been fully appreciated; in fact, most of the troubles connected with steam making can be traced directly to this cause.

It is a well-seated belief among engineers that water must be in continual contact with the surfaces exposed to the

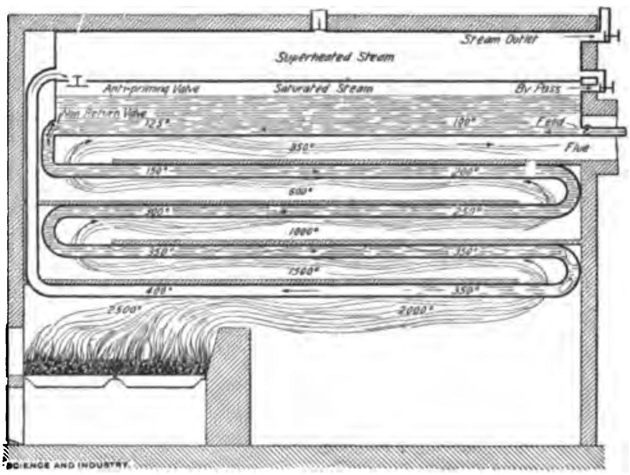


FIG. 2

radiant heat to prevent damage; but how water is to be in continual contact with a square foot of surface which is evaporating enough water to entirely cover it with a layer of steam from ⅛ inch to ½ inch thick once every second has not been explained. Water will not prevent overheating without motion, while steam is most efficient in carrying off the heat if in rapid and constant motion in one direction. Rankine states (p. 261) that the most rapid convection of heat is that which is effected by means of a cloudy vapor, which combines the mobility of a gas

with the comparatively greater conducting power of a liquid.

The principal conditions involved in the evolution of a satisfactory steam generating apparatus may be stated as follows:

In a perfect steam generator—

1. The water and gases must flow in opposite directions to secure the maximum transmission of heat.

2. The flow must be constant and at maximum speed to obtain the highest efficiency of the surface and prevent overheating.

3. There must be no circulation of the water; evaporation must be secured in one circuit.

4. The steam must flow directly from the hottest part of the furnace to the steam reservoir without passing through water.

5. The steam supply must be separated from the water so that priming, foaming, or lifting will be impossible.

6. There must be sufficient steam and water room to prevent excessive fluctuations in pressure and water level.

7. The internal surface must be kept clean automatically and the external surface must be perfectly accessible.

8. There must be no fluctuations in the temperature of the metal; feed-water on hot surfaces must be made impossible.

9. There must be perfect flexibility to permit independent expansion of each part.

10. The apparatus must be simple, with fewest and best joints, and arranged to permit ready access to every part.

11. The apparatus must be absolutely reliable in operation under adverse conditions, with ordinary care.

12. The apparatus must be durable, without frequent repairs, and with freedom from leaks.

The essential elements of a steam-making apparatus designed to fulfil the foregoing conditions are shown in the evaporation diagram (Fig. 2).

There is a dry steam chamber, a water chamber beneath it, a tubular passage extending downward from the water chamber, the lower end of which is connected to the dry steam chamber by a direct upcast passage. An opening between the chambers, controlled by a non-return valve, completes the circuit, and equalizes the pressure throughout the apparatus. The valve prevents "lifting" due to falling pressures, and a by-pass from the steam space of the water chamber to the dry steam chamber prevents excessive difference in pressure during such periods. A non-return valve at the induction end of the tubular passage prevents reversal of the flow.

In operation the water is fed into the lower chamber, whence it flows into the tubular passage and seeks its level in the upcast. When heat is applied, the water is soon driven out of the upcast by the expansion of steam. The result is a column of water against a column of steam, with a constant effort on the part of the water to regain its level in the upcast, which is frustrated by continuous evaporation.

It is a common idea that the "buoyancy" of the steam will prevent the downflow in the passage by its tendency to rise and carry the water with it. We know that gravity affects all matter, and that, theoretically, a pound of steam would fall as fast as a pound of water. That a bubble of steam rises to the top of a column of water is only true when the column is supported. The steam and the water cannot occupy the same space, and the water, being the heavier, displaces the steam and forces it to the top. A column may be part water and part steam, yet the column, considered as a whole,

must obey the law of gravity and will fall unless supported. The laws of hydraulics are as true in a boiler under constant pressure as in a penstock.

The progressive increase in the temperature of the water and the corresponding decrease in the temperature of the gases are indicated by the approximate figures. The bubbles indicate the progress of evaporation, which is completed in the lower tube, and the steam reaches the upcast in a superheated state. With an ordinary boiler the temperature in the upper tube would be higher than the temperature of the gases in this case.

To secure the maximum gravity head of water would require:

a. A vertical downcast with only water in it.

b. A vertical upcast with only steam in it.

c. Complete evaporation secured in a horizontal tube connecting the lower ends of the two columns.

In the diagram the downcast is cut up into bends to give the required length of flow. The effective head will be the vertical distance from the point in the tubes where the solid column of water becomes broken by evaporation to the water level in the drum.

The rate of flow can be changed in three ways:

1. By varying the proportions of the passage and the number of bends.
2. By varying the head of water.
3. By varying the rate of combustion.

The question, then, of keeping the hot end of the tubular passage from getting too hot is merely a question of correct design, since whatever temperature a tube will withstand is no worse for it directly over the fire than near the flue.

The lifting effect on the water, occasioned by falling pressures, affects the gravity force and acts as an instant check on the circulation or flow in any boiler. This effect is neutralized and the flow in the tubes is maintained during periods of falling pressures by the combined action of the anti-priming valve and by-pass. The valve closes at the beginning of a drop, and the by-pass allows sufficient upflow of steam to prevent excessive difference in pressure between the two chambers. The result is that the flow in the tubes is constant irrespective of changes in pressure. The tubes may be automatically flushed by closing the by-pass and causing a drop in pressure in the steam chamber.

The following points may be noted:

The water and gases flow in opposite directions, which is the ideal condition.

The flow is positive, and is most rapid in the bottom tube owing to the expansion of the water into steam.

The flow is independent of any inclination of the tubes, and is as rapid in a horizontal as in a vertical tube.

The upper tubes are always full of solid water, and there can be no water-hammer action.

Evaporation is accomplished without recirculation of the water.

The steam has a short dry passage to the steam chamber, and there is no ebullition or "boiling" action.

The separate chambers for the steam and the water eliminate the possibility of priming or foaming.

The water chamber is a perfect settling tank, owing to the entire absence of ebullition

The pressure and the water within the apparatus can be utilized for flushing the tubes automatically.

The temperature of the heating surface is practically non-fluctuating.

It is a remarkable fact that, while it has been so often recognized that the water should flow from the flue

toward the fire, it has been almost universally assumed to be impracticable, without trial. Rankine states it, and so do Professor Thurston and others.

The practice with "coil" boilers, of which the Belleville is the chief exponent, is to supply the water at the hot end. When the economizers were added to the Belleville by the British Admiralty, the question was discussed of having the flow in the proper direction, but it was decided that it was too dangerous, and the flow was upward as in the boiler.

In conclusion it may be stated that it has been demonstrated by experiment that the same coil will withstand more heat with the water supplied at the cold end than at the hot end, and the reason is not far to seek. In the first case the larger portion of the coil is filled with water and the steam has a free means of escape, whereas in the second case there can be very little water in the coil, and what there is tends to clog the escape of the steam which is mostly generated in the lower tubes and is thus compelled to traverse the entire length of the coil.

THE MAGNETIC BLOW-OUT

ONE of the things that is liable to give most trouble in connection with circuit-breakers, switches or any electrical device when a current is broken between two contacts, is blistering and burning caused by the arc. Many different schemes have been devised to prevent this arcing and thus save the contacts. In some cases a quick, sharp break is depended on to do the work. In other cases the break is made to take place between auxiliary carbon contacts where the burning can do no harm other than to destroy the carbon contacts which are easily renewed.

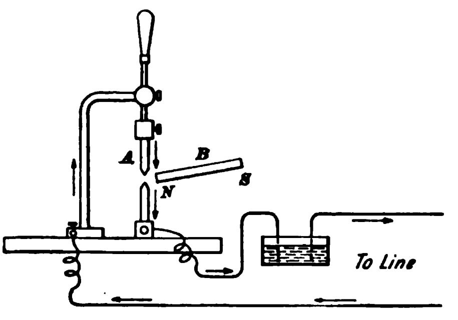


FIG. 1

One of the most effective means of suppressing arcs is the so-called *magnetic blow-out*. This has been applied to many pieces of station apparatus, such as circuit-breakers, lightning arresters, fuse-blocks, etc. It has also been used with success on street-car controllers.

The action of a magnet on an arc can easily be studied by means of a few simple experiments.

If an ordinary open arc lamp is available hang it up so that the arc can be easily reached or, if current has to be used from a power generator, mount a couple of arc light carbons in any suitable support, one above the other, as shown in Fig. 1, and connect a water rheostat in series so as to regulate the current. The upper carbon *A* should be arranged so that it can be slid up and down, but the lower carbon may be fixed in position. Start in with plenty of resistance in the rheostat and the carbons touching each other. Then draw the carbons apart and adjust the current until there is a good strong arc between them. If a regular arc lamp is available these adjustments will not be necessary, as

the regular arc may be used. Procure a strong bar magnet *B* and bring it near the arc, at the same time watching

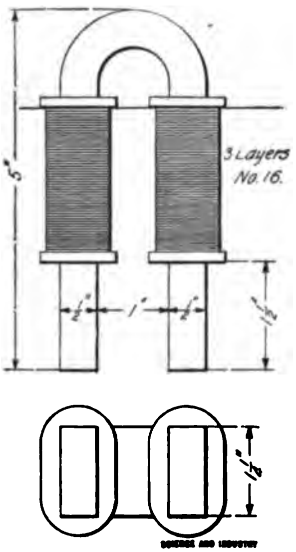


FIG. 2

the arc carefully through a piece of smoked glass. If no appreciable effect is noticed, draw the carbons a little further apart so as to make the arc longer. It will be seen that the arc is forced off to one side and, if the magnet is brought close enough, is extinguished altogether. If the magnet

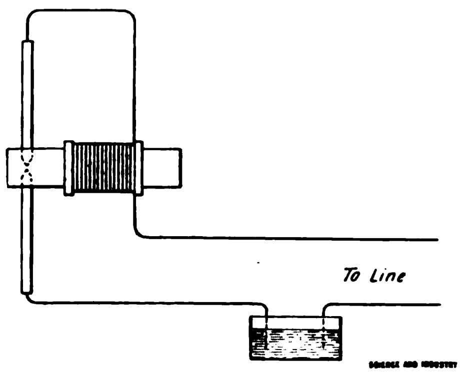


FIG. 3

is turned end for end the same thing occurs, only the arc moves in the opposite direction to what it did before.

This blowing out effect can be made much more striking if a horseshoe electromagnet is employed. Make up a magnet of soft bar iron about as shown in Fig. 2, leaving the polar projections fairly long, say about 1½″. Connect this magnet in series with the arc as shown in Fig. 3. A magnet of this kind will supply a very much more powerful field than a permanent magnet and will blow the arc out much more sharply. In Fig. 3 if the upper carbon is touched to the lower one, and then drawn apart, the arc which is formed will be put out almost instantly.

By holding the magnet a short distance from the arc and gradually bringing it up closer, the arc will bend out or in as the case may be, until finally it is broken. Reversing the connections of the magnet, so as to change its polarity, will reverse the direction in which the arc is deflected. Turning the magnet over or reversing

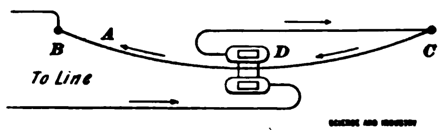


FIG. 4

the direction of the current through the arc has the same effect.

If the magnet is strong enough and if it is properly disposed in relation to the arc the latter will be extinguished almost as soon as it is formed. Where the current is heavy the arc is blown out with a sharp report, and if the arc is formed between metal tips there is but little burning of the metal.

The question naturally arises: Why does an arc behave in this way in the presence of a magnet? In answer it may be said that it is, in fact, the same action that takes place in an electric motor where the conductors carrying current on the surface of the armature core are forced to move across the

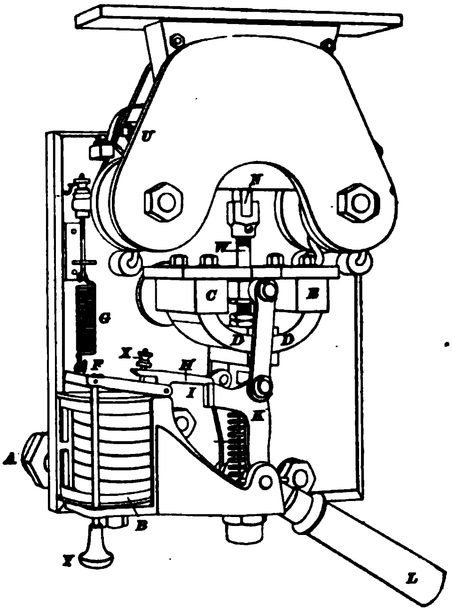


FIG. 5

magnetic field. Any conductor carrying current at right angles to a magnetic field will move across the field if free to do so. This can easily be shown by means of the magnet in Fig. 2. Suspend a bare copper wire, Fig. 4, about No. 16 B. & S., between two supports B C about eight or ten feet apart and allow the wire to have some sag so that it will be free to swing. Connect the magnet D in series with the wire and send as strong a current through them as they will stand. Have the wire A hanging perfectly still and running between the poles of the magnet. When the current is turned on the wire will move either out or in as the case may be. If the magnet be pulled at right angles to the wire, the latter will move also just as if the magnet had an attraction for the wire. If the polarity of the magnet is reversed, the wire moves in the opposite direction.

When an arc is set up between two points we have what is really a flexible conductor of vapor made up of the volatilized carbon or metal. This conductor carries the current across between the tips and, if a magnetic field is present, it will move across the field just as the wire shown in Fig. 4. In moving across the field, however, it stretches out and it is thus made so long that the voltage cannot maintain it any longer and it is broken.

As stated before, this blowing-out action of a magnet has been used to good advantage in circuit-breakers and other pieces of apparatus. A circuit-breaker is called upon to break heavy currents because it is intended to open a circuit whenever the current exceeds a safe value. Fig. 5 shows a view of a General Electric magnetic blow-out circuit-breaker, and Fig. 6 is a sketch of the connections used. The main current enters at A, Fig. 6, and flows through the tripping coil B, thence across the contacts C E and out at M. The main contact D D is made up of a large number of sheets of copper, and when the breaker is set the current flows across from stud to stud through

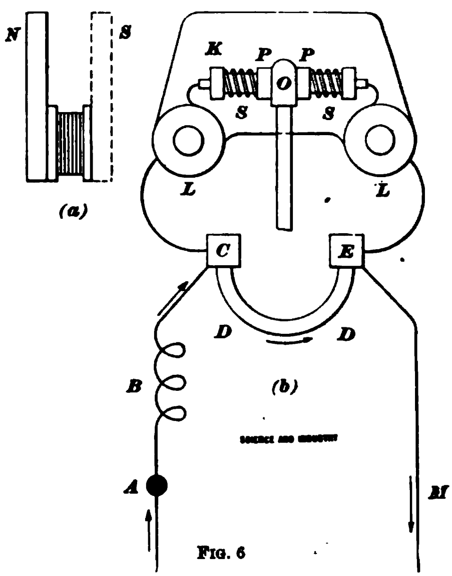


FIG. 6

the contact which is pressed firmly against them. The arc is taken care of at auxiliary contacts *P P* which are connected in parallel with the main contacts *C E*, Fig. 6. These auxiliary contacts are mounted as shown in Fig. 6 between the poles of an electromagnet of which *K* is one pole piece, the front one being removed to show the general arrangement of the contacts. The dotted outline, Fig. 6 (*a*), shows the position of the front pole piece. When the breaker is set *D* is forced up against *C E* and a copper block *O* is forced up between the contacts *P P*, which are pressed against *O* by the springs *S S*. The coils *L L* which set up the magnetic field are in series with this auxiliary break. Under ordinary conditions little current will flow through the auxiliary contacts because the resistance of the main contacts in parallel with them is very low. However, as soon as the main current becomes excessive the breaker trips and the main contact flies down, thus opening the main circuit at *A* and *B*. No arcing occurs at *C* and *E* because contact is still maintained at *P P*. The result is that all the current flows through the auxiliary contacts for an instant and this heavy current sets up a very strong magnetic field that blows the arc upwards and extinguishes it almost instantly and with very little burning at the auxiliary contacts.

The magnetic blow-out is also used on street-car controllers and on a number of different types of lightning arresters. Space does not admit a description of these, but in every case the construction is such that the arc is formed between the pole pieces of an electromagnet and is promptly extinguished by the repelling action of the field.

LATEST EXPERIMENTS OF MARCONI

H. STORRS WEBB

IN THE March issue of SCIENCE AND INDUSTRY, an account was given of the surprising achievement of Marconi in sending the signal for the letter S across the Atlantic Ocean from Poldhu, England, to St. John's, Newfoundland, a distance of 2,100 land miles. Recently he has beaten this performance and has, moreover, taken the precaution to have his results witnessed by reliable parties so there can be no question this time, as there was among a few skeptical persons over his previous experiments, concerning what he has accomplished.

On the 22d of February, he sailed from England for New York, on the steamship Philadelphia, after having arranged to have signals sent to him from Poldhu at certain hours every day. Not only was the letter S sent every day, but messages were also sent with the following results: With ordinary instruments he was able to receive the signal S and messages until he was 1,000 miles from Poldhu. These signals and messages were clearly recorded on the tape of an ink register. The signal S and short messages were received daily until the distance between the ship and Poldhu had increased to 1,551 miles. The last message was received at this distance on February 25. After that no more messages could be detected but the signal S was received until the distance reached 2,420 land miles on the 26th of February; a distance somewhat greater than that covered in the St. John's experiments. All these signals and messages were received in the presence of independent witnesses

who signed their names to the tape records.

The sending apparatus at Poldhu is said to be merely a temporary outfit, and that, when the tower and apparatus now in course of construction at Poldhu is completed, Marconi will have available ten times as much power as at present. Upon the ship the aerial conductor, apparently consisting of 4 wires, extended to a height of 150 feet. It is stated that the limit of the distance over which Marconi's wireless telegraph system will work seems to depend only on the amount of power available, the curvature of the earth being apparently immaterial.

The Umbria, which followed the Philadelphia across the ocean at a distance of only a day's steam, did not receive any of the signals that passed over or around her to the Philadelphia. This is said to be due to the fact that Marconi had his sending apparatus at Poldhu so arranged, or "tuned," as it is called, as not to affect the apparatus on the Umbria, but the apparatus on the Philadelphia being in tune with that at Poldhu, received the signals as long as they were powerful enough. This seems to prove that Marconi can arrange at least two stations so that they will not interfere with one another, and that over a long distance too.

It is reported that Marconi has an agreement with the Canadian Government to establish a station on their coast from which messages may be sent by wireless telegraphy to England. If the attempt is successful the rate for general messages is not to exceed 10 cents a word, about 60 per cent. less than now charged for cablegrams between Canada and Great Britain. The Canadian Government agrees to contribute $80,000 toward the erection of a station in Nova Scotia, the extra cost, if it exceeds that amount, is to be borne by the Marconi company. The Canadian Government will transmit all messages received by the company over its own telegraph system on land at rates not higher than now charged for ordinary messages.

The latest achievement in sending signals by wireless telegraphy by Marconi cannot be doubted in view of his witnesses, even if his own word was not sufficient.

It is to the credit of most scientific men that his previous achievement was not doubted when they learned what he had accomplished over his own signature. In other words, they never doubted his word or statements, although some few did hesitate to accept the ordinary press reports. It now looks as though wireless telegraphy across the Altantic Ocean will be a success at no great distant day, and the credit for its accomplishment will certainly belong to Marconi.

TYPE-PRINTING TELEGRAPH

THE Baudot multiplex typeprinting telegraph is said to be operating very successfully on the Berlin-Paris telegraph line. The whole telegraph business between Berlin and Paris, which heretofore required five telegraph lines, can now be easily done over one by means of the Baudot system. The operation is said to be uninfluenced by minor interruptions of the current. The work for the operators is not more arduous than with the Hughes apparatus, which has been replaced by the Baudot system.

SHEAR

H. ROLFE

THE STRENGTH OF MATERIALS TO RESIST DISTORTION—INSTANCES WHERE THE SHEARING STRENGTH IS CALLED INTO PLAY—A CASE IN POINT FROM CAR PRACTICE

WHENEVER two machine parts, or, for that matter, any two bodies, whatever their nature or intent, are held together and are intended to resist any tendency to produce in them relative motion, they do so by virtue of the strength of the component materials to resist tension, compression, or shear; or, perhaps the effect of some two or of all three of these properties is called into play. These resisting forces may be, and generally are, aided by frictional resistance also.

Fig. 1 is a case of pure tension, this being the only force called into play, so far as the body of the bolt is concerned; Fig. 2 is one of compression only; Fig. 3 one of shear, as regards the bolt *B*. If, however, this is a slack fit in its hole and there is much play in the jaw, there will also be bending as well as shear.

This property of shearing resistance in a metal is often made use of in machinery. When a connecting rod has an end like that in Fig. 4, all the pull of the steam, and also the inertia

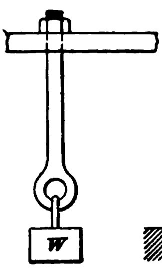


FIG. 1

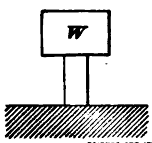


FIG. 2

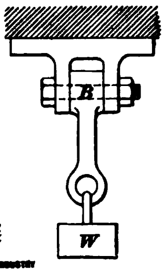


FIG. 3

stresses at the end of the stroke are taken up by the tensile resistance of the bolts *B*. In Fig. 5, however, the pull is taken up by the shearing resistance of the bolts *B*. As a matter of fact, some part of the pull in Fig. 5 is taken up by the frictional resistance to slipping engendered by the grip of the

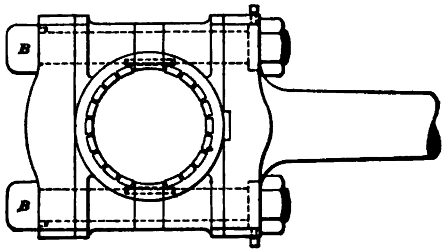


FIG. 4

strap *A* on the butt end *C*. In Fig. 4 this effect is wholly absent; and we may here observe that the aid thus rendered by friction is in this and all similar cases (also in boiler and bridge work) always ignored by the designer, or, to speak more accurately, is neglected by him, any benefit that may accrue from its presence being "thrown in," so to speak. In many cases it may happen that the body which resists being moved (relatively to some adjoining part) does so by virtue of its resistance to all the above stresses—tensile, compressive, and shearing. Thus, in Fig. 6, the pole *A* is subject to the action of all these forces at one and the same time. The torque acts as shown at *F*, the dead weight of the pole as at *W*, while there may also (depending on the winding) be an unbalanced magnetic pull *P* of the armature (due to displacement relatively to the field) acting normally as shown. The pole is bolted to the frame by bolts *B*, the tightening up of which induces a tensile stress in them. The pull *P* throws *B* also into tension, although these two tensions

are not additive. F and W induce in the bolts a bending stress—which involves both tension and compression, tension in the upper half of the bolt

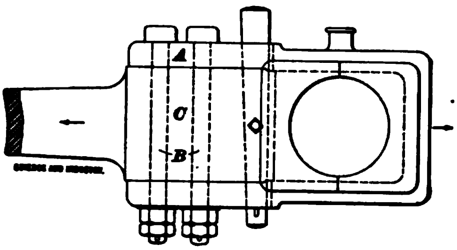


FIG. 5

section. and compression in the lower half. The downward pull of W and F is taken up by the resistance to shear of B. The amount of this shear is that due simply to the weight W and the torque F. The amount of bending stress wil vary with the leverage that W and F may happen to possess.

There is another force often at work, that of torsion. When a man is tapping a hole by hand, he puts the tap into pure torsion, so long as his hands are equal distances from the tap, and exert the same push and pull. If one of these efforts exceeds the other, bending takes place, albeit the leverage may vary correspondingly, and make the moment of each hand the same. Thus, a beginner using a single-ended tap wrench is very liable to break the tap, unless, as the workman instinctively does, the fingers are held on the tap to "steady it"—really to hold up against the pull of the wrench, which tends to bend the tap. Of course, instead of merely pulling at the wrench, it should be so grasped and actuated as to supply a thrust against the tap, so as to produce the net effect of twisting only.

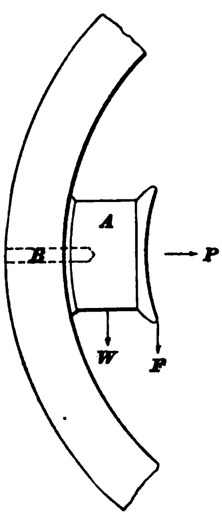


FIG. 6

When screwing up a bolt, if we could imagine the surfaces of nut and screw threads to be frictionless, the bolt would suffer only pure tension. As a matter of fact, there is always torsion too. This torsion or twisting induces a shearing stress, the tendency being to make any two contiguous particles in adjacent transverse layers slide across

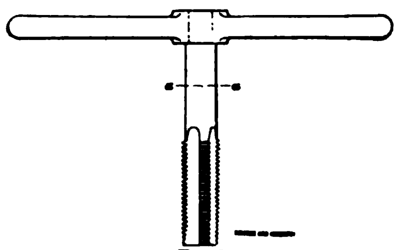


FIG. 7

each other, but whereas in Fig. 3 the shearing stress is uniformly distributed over the cross-section of the bolt, the stress in any cross-section $a\ a$, of Fig. 7, is not uniformly distributed, but is greatest at the outer surface and diminishes toward the center.

Now, when a body is subject to two kinds of stress, such as tension and torsion, the resultant stress, both of tension and of shear, is greater than either considered separately. When, then, we have a bolt intended to resist shear, as in the case of a connecting-rod end, it is obviously desirable to restrain the stress to one of shear only. With this in view the bolts are made, a reamed driving fit, tapered too, so that they may be the more easily put in and removed, the contact period of hard driving being less than if parallel.

Sometimes separate pieces are put in to take the shear, instead of the bolts

sustaining it all. Thus, in Fig. 8, the keys *a* take up some of the shear, while in Fig. 9 the shoulder *b* on the block *E* serves a similar purpose. How much of the shear the parts *a a* and *b*, respectively take up in each case depends on the fit of the keys and bolts. We remember to have seen double **V** pieces in some main rods in Europe, as in Fig. 10. Here the pull *P* of the piston is taken up by the large key *D*. When driven down, this key tightens the strap *A* up against the wings *w*, which being **V**-shaped press the strap down on to the butt and so hold the latter closer against the opening effect due to weight, to the inertia of the rod when running, and also to the angular thrust. In such rods, though, the

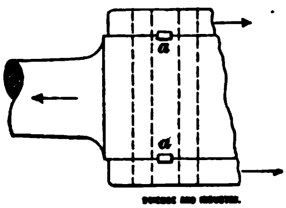


FIG. 8

restraining influence of the wings diminishes toward the front end *E*, and evidently the designer's intention was to let the keys *a a* act as a bolt and clamp down the strap to the butt, for any springing open of the strap gives the brass more play and so produces knock and wear in the strap. Of course the keys *a a* are available to take up some of the shear, their share in this duty depending on the fitting in of them and of the key *D*; this latter is driven down before *a a* are put in. Obviously, however, the main function of these pieces is not to take the shear (as in Fig. 8 or 9), for, if so, the least area would not be placed on the line of shear—namely, the joint or common surface between the strap and rod. In early days locomotive practice, the rod ends used to have only gib and cotter, and no bolts; the brass being drawn up against the butt when driving the cotter down—no separate cotter being

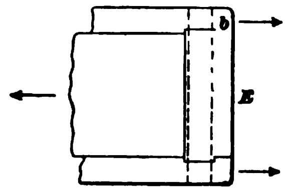


FIG. 9

used for the brass, as in Fig. 5 and 10.

Here the springing-open effect was resisted only by the ends of the gib, an unsatisfactory and certainly unmechanical arrangement for high-speed engines, less objectional, of course, for slow-rotating engines—such as large stationary ones—for which this design is still in use. Here, now, the keys *a a*, Fig. 10, would have been exactly the thing, only the very essence of the design was that the strap should move up on the butt when taking up the play; hence, the keys *a a* were of course out of the question.

The wear that may come on a bolt through the pull of the rod is considerable, especially if slack to begin with and much knock is subsequently allowed to accumulate. The wear will then be concentrated at the joint, the tendency of the bolt being to assume

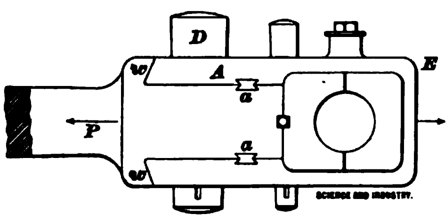


FIG. 10

the position shown exaggerated in Fig. 11, the slight play allowing the flexure to occur. When the surface of the bolt is thus grooved, it cannot be

remedied, for turning it down would make it too slack, of course. The keys *a a*, on the other hand, can be easily renewed.

In designing a joint, where shear

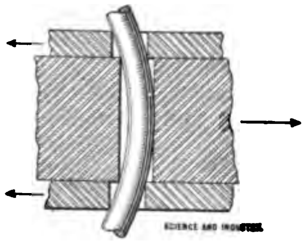


Fig. 11

comes into play, it should be noted whether the bearing area is large enough; it might happen that the parts were strong enough in tension and in shear, but that too little surface was exposed to the pressure and that, as a result, a compression took place all over the bearing surfaces. This matter of bearing area has to be looked to—especially does it occur in bridge and roof work. Here the plates might be strong enough and the rivets have enough shearing strength, but the plate might be so thin that the area offered to the rivets would be too small, and crushing result, thus enabling the joint to yield and unduly strain some other part. The point in

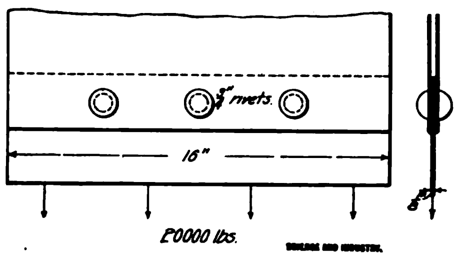


Fig. 12

question may be readily illustrated by Fig. 12, an extreme case, and shown thus exaggerated merely for example. Here the plates are strong enough, and also the rivets, but the contact area between the two is too small. Thus, the area to resist tensile stress is 2 sq. in., the shearing area of rivets is nearly $2\frac{5}{8}$ sq. in., whilst the area of metal in contact to take up the crushing effect due to the pull is not much more than $\frac{1}{4}$ sq. in.

A query was recently sent in, asking about the advantage given by the use of a lock plate in the draft gear of cars. Fig. 13 (*a*) shows such an arrangement, in which the draft timbers are bolted to the under side of the sills *S*. Sometimes they are put in between these latter. Now, if the plate, Fig. 13 (*b*), were not there, the pull of the drawbar would all come on the bolts *B*, Fig. 13 (*a*). These are not likely to be a very good fit to begin

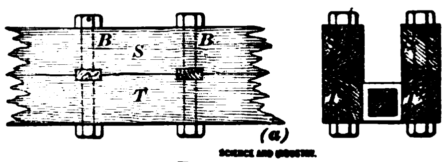


Fig. 13 (*a*)

with—the accuracy of such work being very different from that of engine work, of course. The relative motion of the timbers in opposite directions is all taken up by the shearing resistance of the bolts, and also, of course, by the crushing strength of the surface of the timber with which the side of the bolt is in contact—the inside of the bolt holes, in fact. Now it will be readily seen that this is an unfavorable arrangement. If the timber *T* were in between two sills the case would be better, *T* then corresponding to the rod of Fig. 5, and the sills *S* to the strap. Here, however, the lower timber pulls away, as in Fig 13 (*c*), and the bolt takes the position shown exaggerated, thus localizing the pressure at the points indicated and readily crushing the sides of the hole and adding to the play. Then when the next shocks

and jerks come on the gear, the play increases their impact and so wear increases continuously. Thus, unless the two surfaces are equally hard, and

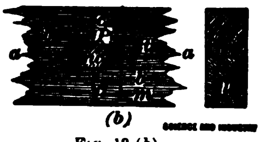


FIG. 13 (*b*)

a good fit to begin with, this arrangement is a bad one. Fig. 5 is better, as offering more resistance to relative displacement of the bolt, and also putting the latter into double shear.

To improve the present arrangement, builders put a key in between the joint, as in Fig. 13 (*b*). This, if a good fit in the direction of the pull, will take up the shear from the first and in the most effective manner. This key is usually cast iron, the draft timbers of oak, and the sills of pine. In regard to the strength of the joint when the lock plate is used, it may be said that this is most probably one of those cases where the designing is "by eye"; still, the strength of the joint, *on paper*, may be computed thus: The bolts serve simply to keep the parts together, and we will suppose the plate *P*, Fig. 13 (*b*), takes all the pull. The joint could fail by shearing the timber on *b* or *b'* or by pulling apart at *c* or *c'*. The first contingency is, as a matter of fact, out of the question, and the second practically so; also the key being cast iron is safe. The thing to be careful about is to make the key of sufficient area so as not to crush into the wood. If the length of the key in the wood is $2\,l$, and width w, the resistance of the key to shear is $2\,w\,l\,f\,s$ when $f\,s$ is the ultimate shearing strength of the metal. If the plane marked *b* were of length m, and if $2\,l$ were its transverse dimension, its strength would be $2\,m\,l\,f\,s$, $f\,s$ being the shearing strength for the timber in question. If $f\,c$ is the

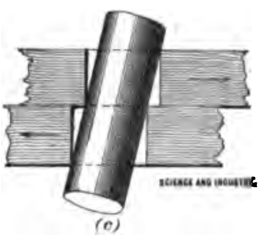


FIG. 13 (*c*)

crushing strength of the timber, the strength of the surface taking up the end thrust of the key will be $2\,l\,t\,f\,c$. There may be two, three, or more keys.

STEAM BOILER INSURANCE COMPANIES AND STEAM USERS

R. S. KEELOR IN THE PRACTICAL ENGINEER

THE attitude of insurance companies toward engineers, and the value of the services rendered by these companies to the owners of steam boilers and to the engineers entrusted with their operation, are matters which are not so generally understood as they should be, hence the writer wishes to call attention thereto by way of introduction, since what he shall have to say will be stated from the insurance company's point of view, and it may be assumed that any discussion from such point of view is not without some warrant when it is remembered that the insurance companies of the United States have paid more than one million seven hundred and fifty thousand dollars in losses upon boilers that have exploded.

Insufficient attention is apt to be bestowed on questions that should be carefully considered before a boiler is installed, and where the selection has

fallen upon a type of boiler not adapted to the conditions under which it is to be operated, or where the chemical and physical conditions affecting the supply of water to the boiler have not received proper attention, defects must soon develop. That bad management or the subordination of well-settled principles in chemistry and steam engineering to the ordinary notions of economy may quickly ruin a good boiler and cause its explosion is a matter of oft-repeated experience, and the companies whose total risk upon insured boilers in the United States amounts to more than four hundred and seven million dollars have, through self interest, been compelled to develop a corps of specialists known as Steam Boiler Inspectors, whose knowledge is made available not only for the proper safeguarding of the companies' interests but for the advancement of the science of engineering in general. The training of these men as inspectors has involved an outlay of more than twenty-two million dollars. The figures here given point in a significant way to the value of inspection as applied to steam boilers; but they tell only a part of the story. Statistics show that the average life of insured steam boilers is fully fifty per cent. longer than in the case of uninsured boilers, because the insurance company is interested in the detection of those hidden defects that cause the boiler to wear out if it does not explode, but the service of the insurance company should not stop here. A one hundred horsepower boiler, if properly set and kept in good condition, will, under right management, consume 24,000 tons of coal in twenty years, but where these matters do not have proper attention the consumption of coal will be enormously increased. The properly equipped insurance company has in its service experts who are qualified to furnish specifications for the construction and setting of boilers adapted to any stated purpose or requirement, and yet other experts whose duty extends to analyzing the waters with which boilers are supplied, with a view to the application of antidotes to counteract the baneful effects of bad water. There are a number of harmful acids and mineral matters found in various combinations in different samples of feedwater, and these form a stone-like incrustation, or in some cases corrode the inside of the boilers or their connections. This, of course, increases the thickness of the surface through which the heat must pass from the coal, and consequently demands more coal to produce a given result, and there is always danger that the circulation of water within the boiler may be shut off by the complete closure of a tube or pipe through the accumulation of such incrustation, and then an explosion occurs. As previously stated, the experts in the service of a boiler insurance company may save coal for the owner of a boiler and prevent an otherwise certain explosion by making a timely diagnosis in the matter of bad water or incrustation. The application of proper antidotes to feedwaters will promptly affect the transformation of their contents of mineral matters from hardenable elements into unhardenable, simply rotted, inert, earthy oxides, with all of their physical properties, and capacity to solidify, completely destroyed. But the more numerous class of men in the service of these insurance companies are the inspectors who visit the boilers four times a year. These are the men who, with candle, hammer, and plastic clay, and with eyes and ears trained by experience, find their way into many sooty flues; hidden defects that one not specially trained would fail to dis-

cover are quickly found by these men. The duties of the boiler inspector constitute a hard and thankless task, and, strange to say, his work is often made more difficult by imposing obstacles where co-operation upon the part of the owner of a boiler is dictated by every consideration of safety and real economy. The writer has encountered an instance quite recently where the owner of a battery of boilers that have been in use some years expressed his regret that he could not take advantage of a lower rate for insurance than he is now paying, because his boilers had been in service so long that he feared another insurance company would condemn them, thus necessitating a large outlay for new boilers—an outlay which he did not feel he could afford at this time.

In the process of rolling the boiler plate local imperfections called "laminations" occur. Frequently these laminations cannot be detected when the boiler is constructed.

Iron or steel that has become laminated in the process of rolling is weak at the point thus affected, and blisters when put into active service; therefore it becomes still weaker at the point involved and will not stand the pressure to which a good boiler is subjected, and this is one reason why new boilers sometimes explode.

Defective riveting may also lead to rupture or explosion of a comparatively new boiler.

The ordinary inspection made before a new boiler leaves the shop is known as the hydrostatic test, and consists in subjecting the boiler to the strain of water under pressure effected by a force pump. This same test is used by City, County, and State Inspectors where boiler inspection is regulated by law, and is frequently relied upon as a sufficient test for boilers that have been in use. The boiler about to be tested in this way is first filled with water and the pressure is then gradually increased.

Experience teaches that a boiler that is capable of standing this gradual increase of pressure may explode under steam pressure, as was the case at the Baldwin Locomotive Works in Philadelphia recently, when a water tube ruptured, bringing death to four employes. A similar accident occurred at Baeder & Adamson's Works in Philadelphia in December, 1899, resulting in the death of two employes. These two accidents very forcibly illustrate the fact that tubular boilers are not entitled to be called "safety boilers," if by such designation it is meant to convey the idea that they will not rupture or explode, and that they are incapable of doing harm.

Boilers properly constructed and made of good iron or steel become "pitted" internally from chemical action or corrosion after they have been in use. *This introduces a hidden source of danger*, because pitting may extend a considerable distance through the thickness of the boiler sheet and reduce the strength of the boiler proportionately, and cause the material to rupture at the point thus affected; but, as in the case of defective riveting or a laminated boiler sheet, the gradual increase of pressure employed in the hydrostatic test may fail to detect the weakness.

More than $1,750,000 have been paid by insurance companies of the United States for losses upon boilers that have exploded or ruptured, and these same companies have paid about $21,875,000 to a body of men whom they have trained as experts, to inspect the insured boilers and reduce the risk of explosion to a minimum.

Where inspection fails to prevent an explosion insurance pays the loss.

About four thousand boilers have exploded in the United States within a period of twenty years, resulting in the death of five thousand persons and the injury of eight thousand more. The cost of insurance is merely nominal when compared with the advantages gained by the owner of the boiler.

The risk of an explosion which may cause loss of life and serious damage to property is reduced to a minimum, the life of the boiler is prolonged, and the saving in fuel amounts to more than the insurance costs.

SAFE WIRING RULES

A WORKMAN should thoroughly familiarize himself with the rules and requirements of the National Board of Fire Underwriters before attempting to do any electrical construction. The rules are all based on good engineering practice and are a necessity for the prevention of unreliable and dangerous work.

The following are a few of the more important suggestions given in the code and are applicable to all electric light, heat, or power construction.

In all electric work, conductors, however well insulated, should be treated as bare, to the end that under no conditions, existing or likely to exist, can a grounding or short circuit occur; and so that all leakage from conductor to conductor, or between conductor and ground, may be reduced to the minimum.

In all wiring special attention must be paid to the mechanical execution of the work. Careful and neat running, connecting, soldering, taping of conductors, and securing and attaching of fittings, are specially conducive to security and efficiency, and will be strongly insisted upon.

Wires must not be of smaller size than No. 14 B. & S., except when used for wiring fixtures or by special permission. Wires must be separated from contact with walls, floors, timbers, or partitions through which they may ᐧss by non-combustible, non-absorptive insulating tubes, such as glass or porcelain. Bushings must be long enough to bush the entire length of the hole in one continuous piece.

Transformers must not be placed inside of any building, excepting central stations, unless by special permission of the inspection department having jurisdiction. They must not be attached to the outside walls of buildings, unless separated therefrom by substantial supports.

Switches must be placed on all service wires, either overhead or underground, in a readily accessible place, as nearly as possible to the point where the wires enter the building, and arranged to cut off the entire current. Knife switches must be so placed that gravity will tend to open rather than close the switch. They must not be single-pole, except where the circuits which they control supply not more than six 16 c. p. lamps, or their equivalent.

Automatic fuse cut-outs must be placed on all service wires, either overhead or underground, as nearly as possible to the point where they enter the building and inside the walls, and arranged to cut off the entire current from the building. They must be placed at every point throughout a system, where a change is made in the size of wire (unless the cut-out in the larger wire will protect the smaller). All cut-outs must be in plain sight, or

enclosed in an approved box, and readily accessible. They must not be placed in the canopies or shells of fixtures.

Circuits or groups of incandescent lamps requiring more than 660 watts must not be dependent on one cut-out. Special permission may be secured for departure from this rule in case of large chandeliers, stage borders, and illuminated signs.

No fuse must have a rated capacity exceeding the allowable carrying capacity of the wire it protects.

In open-work wiring, supports must be placed at no greater distance than 4½ feet apart.

The following is a table showing the safe carrying capacity of conductors of different sizes in B. & S. gauge as given in the rules.

B. & S. Gauge	Rubber-Covered Wires. Amperes	Weather-Proof Wires. Amperes	Circular Mils
18	3	5	1,624
16	6	8	2,583
14	12	16	4,107
12	17	23	6,530
10	24	32	10,380
8	33	46	16,510
6	46	65	26,250
5	54	77	33,100
4	65	92	41,740
3	76	110	52,630
2	90	131	66,370
1	107	156	83,690
0	127	185	105,500
00	150	220	133,100
000	177	262	167,800
0000	210	312	211,600

— Electricity.

MATERIALS OF ENGINEERING—II

WILLIAM BURLINGHAM

IN the former article on the Materials of Engineering, we treated the subject of Steel; that is, a material made from the base, cast iron. This latter metal is really the parent of our principal structural materials, and cast steel, forged steel, and wrought iron differ from each other merely in the varying amounts of carbon in combination with the iron. The chemical symbol for iron is *Fe*, the abbreviation of the Latin word Ferrum, meaning iron. These metals approach each other so closely that it is very hard to distinguish the point at which wrought iron becomes steel, and cast iron becomes wrought iron.

A short account of the making of cast iron, from the iron ore, as dug in the mines, will be of advantage to the student in Mechanical Engineering.

In the United States the manufacture of cast iron may be divided into two periods: First, from the smelting works of the London Company in Virginia in 1620 to the end of 1862; and second, from 1863 to the present time.

In 1791 we hear of the first grumbling of the English people because of the dangerous rivalry of our country. They grumbled a bit early, it is true, but the events of the last few years, or 100 years after 1791, find us leading the world in the production of cast iron. The first anthracite furnace for smelting was built in 1837.

Our country is the natural home of the iron manufacturer, deposits of ore being found in nearly every State in the Union; and this, in combination with our unequaled agricultural lands, is one of the principal causes of our present high standing amongst the nations of the earth.

Michigan, on the lakes; the Alleghany range of mountains; Missouri, Ohio, Illinois, and Indiana, contain probably the most valuable beds of ore.

The principal ores are:

First.—Magnetic iron oxide, or mag-

netite, found in the United States in Michigan, New York, New Jersey, New England, and North Carolina. It makes excellent iron and the very best steels.

Second. — Franklinite, which is worked for the zinc it contains, and is then reduced to the compound known as spiegeleisen.

Third.—Red hematite, which is nearly as rich in ore as the magnetite. The ordinary red ochre is one variety of this ore. It furnishes nearly all the cast iron for the raw materials of the Bessemer process for making steel. It also makes the finest malleable irons.

Fourth.—Brown hematite. From this the principal varieties of foundry iron are made. Salisbury, Conn., is a famous producer of iron from this ore. It underlies the Alleghany and Appalachian range of mountains their entire length, and there are immense deposits in Alabama and other Southern and Central States.

Spathic iron ore, clay iron ore, and blackband ore are rarely worked in the United States, although they yield nearly one-half the iron made in Great Britain.

Iron pyrites, or fool's gold, is used only as a source for obtaining sulphur. The Virginia and North Carolina Chemical Co. own immense deposits in Virginia. Chrome iron ore of late years has become prominent in the making of chrome steel. In the United States it is found in Maryland, Pennsylvania, and North Carolina.

The above constitute the principal iron ores in commercial use. There are several others, but the percentage of iron is not up to the standard, and it is mixed with so much phosphorus, sulphur, etc., as to render it very undesirable.

The value of an ore depends upon, first, its quality; that is, its chemical composition; second, the relative proportion of these chemical elements; third, its physical character; fourth, the relative cost of mining it compared to the market price.

The ore supplied to the furnace must undergo three preparatory processes:

First.—Grading, that is sorting the several grades into separate bins.

Second.—Calcination, or roasting. Calcination is the exposure of ore to a moderately high temperature with or without access of air; roasting, the heating of the ore to a higher temperature, but under the fusing point, with access of air. Magnetite and hematite ores are not subjected to this process.

Third.—Mixing the ore charge.

Roasting is done in heaps or in kilns; generally speaking, by placing ore and fuel in alternate layers upon each other, and burning gradually. The ores lose from 3 to 5%, where nearly all oxide, to about 25%, where clay ores are used.

The make-up of the furnace charge is an operation that, in these modern times, demands high chemical knowledge and great practical skill in the actual experience of furnace management.

The charge is proportioned according to the character of the ore, fuel, flux, and the size and methods of working the furnace, and by the character of product required.

Fuel.—Charcoal contaminates the product least; coke, carefully selected, is good fuel; while bituminous coal, because of its sulphur, is only used for making the cheapest grades of iron.

The usual flux is limestone. Fluorspar is sometimes used with this. Care is always taken that these fluxes are free from phosphorus. Silica, alumina, and magnesia are required, but are usually found in the ores. The parts of the charge are weighed separately and spread out on a floor, the furnaces being charged with the requisite

number of barrow loads from each heap.

The ordinary coke furnace is about 80 feet high, circular in section, smaller in diameter at the top and bottom than it is about one-fourth the way up, where it is one-third greater in diameter than at the top. It may best be described as being like a great pear-shaped chimney.

The process of charging a furnace requires great care and much time, as too rapid charging creates unequal and high temperatures, cracking the furnace lining and causing, possibly, much damage. A small fire is first made in the crucible, warming the masonry and furnace walls. This fire is kept up constantly and very gradually increased by small additions of fuel, ore and flux, until the furnace is filled to the mouth. This takes a week or more. As the furnace becomes hot enough to reduce the ore and melt the cinder, more and more ore and flux are added, and the blast turned on. The smelting is now on, and the furnace is said to be in blast. After a few weeks, the maximum amount of iron is produced, the furnace melting all the ore and flux it is capable of. This blast may be on for a month, or for five or six years. When it is decided to place the furnace out of blast, the same care is used as in starting; the proportion of ores in the charge is gradually reduced, and the limestone increased until when the fire is out, the furnace is full of burned limestone.

The operation in the furnace, briefly stated, is as follows:

The charge descending very slowly from the top, meets the air from the tuyeres. This air meeting with fuel at an extremely high temperature, the oxygen unites with the fuel carbon, forming carbonic oxide and carbonic acid. This meeting with other fuel, carbon monoxide is formed; higher up another atom of oxygen is taken up, forming carbonic acid, and in that state passing out at the top of the furnace.

The iron running from the furnace is conducted by channels to the "pig bed." This consists of a level surface of sand, channeled longitudinally and transversely, forming molds. The main channel is called the "sow," and the small channels, each about 4 feet long, branching off from the "sow," are called "pigs." If forge iron of high grade is to be produced, the metal is often cast in iron molds to avoid undue silicon.

The "sow" is usually remelted. The gases of the furnace are led to the hot blast stoves and the steam boilers. The hot blast stoves are used for heating the air that is to be forced through the tuyeres into the furnace.

The product of the blast furnace is cast iron, or pig iron, as it is commonly called. This is metallic iron, chemically united with from 5 to 10 per cent. of carbon, silicon, and some other elements.

Carbon combines with iron in two ways, chemically and physically; as a carbide when united chemically, and as graphite when united physically.

The small black streaks and spots that shine in a casting are the physically combined graphite.

The ordinary classifications of iron are as follows:

Foundry Iron, No. 1: Dark gray fracture, high metallic lustre, large crystals, makes fine castings, flows freely, soft and somewhat ductile. No. 2: Gray iron, fracture gray, lustre clearly metallic, free melting, free flowing, ordinary strong iron. No. 3: Light gray iron fracture. Nos. 4, 5, 6: Forge irons, are generally used for conversion into wrought iron by puddling.

American pig iron of good quality contains about 6½% of foreign matter.

A cast iron, which was rejected as unfit for use in large castings because of its liability to crack, contained .81 sulphur, .049 phosphorus, and 3.08 per cent. of silica.

A specimen of good machinery iron for castings contained .053 sulphur, .47 phosphorus, and 1.37 silica.

Good cast iron melts at about 2,732° Fahrenheit. The expansion of cast iron when hot is about ⅛ inch to the foot; and a patternmaker's rule is 12⅛″ long for every foot, thus insuring that his pattern is ⅛″ longer in a foot than the casting will be.

TENACITY OF GOOD CAST IRON

	Lb. Per Sq. In.
Good pig iron	20,000
Tough cast iron	25,000
Hard cast iron	30,000
Good tough gun iron	30,000

TENACITY OF REMELTED CAST IRON, NO. 1 PIG. SALISBURY

	Lb. Per Sq. In.
First melting	14,000
Second melting	22,900
Third melting	30,229
Fourth melting	35,781

COMPRESSION, CAST IRON

	Lb. Per Sq. In.	*Per Ct. Comp.*
No. 2 iron	81,488	9.48
No. 2 iron	89,127	8.72
No. 2 iron	91,674	5.86
No. 4 iron	127,323	9.95
No. 4 iron	127,323	9.50

The requirements of the British Admiralty for cast iron are as follows:

"Test pieces to be taken from such castings as the Inspector may consider necessary. The minimum tensile strength to be 9 tons (20,160 lb.) per square inch taken on a length of not less than 2 inches. The transverse breaking load for a bar 1 inch square, loaded at the middle between supports 1 foot apart, is not to be less than 2,000 pounds."

The standard of the American Manufacturers for structural iron is as follows:

"Except where chilled steel is specified, all castings shall be tough gray iron, free from injurious cold-shuts or floor holes, true to pattern and of a workmanlike finish; sample pieces, 1 inch square, cast from the same heat of metal in sand molds, shall be capable of sustaining, on a clear span of 4 feet 8 inches, a central load of 500 pounds, when tested in the rough bar."

The requirements of the United States Bureau of Steam Engineering for cylinders, liners, valve chests, and other important parts are as follows:

"The grade and quality of the steel will be specified on order. The castings must be free from blowholes, porous places, shrinkage, or other cracks or defects.

If the Inspector has doubts of the quality of the material in any casting, he may make tests at the expense of the contractor. The minimum tensile strength of the material shall be 20,000 pounds per square inch, the length of the test piece being not less than 2 inches. The transverse breaking load for a bar 1 inch square, loaded at the middle and resting on supports 1 foot apart, shall be not less than 2,000 pounds.

The scale shall be removed from the unfinished parts of the insides of all cylinder covers and valve-chest covers, and from their liners, either by pickling or other approved processes as may be required by the machinery specifications."

The preceding specifications refer to iron after it has been melted in a foundry cupola and not to the pigs as delivered from the blast furnace.

The process of casting in a foundry is quite similar to that of the blast furnace.

The iron is melted in furnaces called "cupolas," of which there are two principal types, viz., oblong and round, the latter being generally used. The common sizes range from 30 inches to 48 inches inside diameter. The height

ranges from 7 to 14 feet according to the diameter. High cupolas hold the heat, make the iron hotter, and melt it faster.

The method of procedure of cupola casting is as follows:

In the morning the melter will inspect the interior of the cupola, pick it out and daub it about an inch thick with fireclay; after the clay is daubed, the bottom is put up and covered with sand from the dirt piles in the foundry. After the sand is rammed down it is preferable to coat it with a clay wash, as by so doing a crust will form on the top of the sand. This bottom should be made sloping toward the tapping hole. Coal generally makes a purer and softer casting than coke, and it requires more fuel to melt heavy iron than light, and pig than heavy scrap, because of the sand on the pigs. Coke will melt iron faster than coal, but the cupola will melt longer with coal than with coke.

Coal and coke are often used together. Some foundries make a bed of coke and coal, and some all coke. There are various mixtures, but they are dedependent to a great degree on the comparative cost of the two fuels.

The fire is started with kindling wood. The cupola should be allowed to warm up before any iron is charged. An average time is about two hours between lighting fires and charging with iron.

The iron should be charged, say, a half hour before the blast is put on. The cupola is now charged with alternate layers of fuel and iron in proportions dictated by experience for the class of castings desired or size of iron to be melted. Sometimes oyster shells or Fluor-spar are used as a flux during the latter part of the heat. As the iron melts, it is run off through the tapping hole to the ladles. When a ladle is filled, the melter stops the tapping hole with a plug made of new moulding sand dampened with clay wash.

The following gives the proportion of mixtures for first-class cylinders and liners, such as are used in the United States Navy. They are from the foundries of prominent shipbuilders.

1. No. 4 Muirkirk.

2.	Machinery scrap 2 Car wheel scrap 1 Salisbury pig 1	or	Old cannon balls 2 Old cylinders 1 Salisbury pig 2	
3.	Muirkirk 60% No. 2 Shelby 25% No. 3 Shelby 15%		No. 4 Shelby 20% No. 4 Muirkirk 20% No. 3 Shelby 20% Machinery scrap 40%	

New York Navy Yard—

Cylinder Liners.

Salisbury	800
American charcoal pig	800
No. 1 machinery scrap	2,900

Cylinders.

High pressure—	
Salisbury charcoal	20
No. 2 American pig	15
No. 1 American pig	10
No. 1 machinery scrap	65
Low pressure—	
American charcoal pig	10
No. 1 American pig	10
No. 1 machinery scrap	60
For ordinary machinery castings, the following:	
No. 3 Allegheny	20%
No. 3 Princess	20%
No. 2 Lowmoor	20%
Scrap	40%

The above mixtures will give a good idea of the practice of the best foundries in the use of charcoal and coke irons with machinery scrap.

The preceding remarks are intended for a general review of the subject and to give the ordinary reader an idea of the processes that the ore undergoes in its transmutation into the casting of the machine shop. The subject is too extensive to detail minutely, and any particular knowledge that the reader requires may be found in the various technical works bearing upon the subject; and, for a successful working knowledge of the processes, the actual apprenticeship must be served, as the successful manufacture of iron in all its stages depends upon the working chemist and working furnace or foundryman.

The following log of a cupola from actual practice will be found interesting, showing, as it does, the amount of charging, time of blast, length of heat, etc., and the proportion of fuel to iron melted.—(We are indebted to the publication of Mr. Thos. D. West for this information.)

Outside diameter	72 in.
Thickness of lining	9 in.
Inside diameter at tuyeres	54 in.
Largest inside or melting-point diameter	56 in.
Inside diameter at charging door	54 in.
Height from bottom plate up to bottom of charging door	12 in.
Style of tuyeres: flat 1 in. opening continuous tuyere	
Height from bottom of plate to bottom of tuyere	20 in.
Height of tuyere above sand bottom on back side	14 in.
Height from bottom plate to bottom of slag hole	16 in.
Fuel used for bed: coke	1,400 lb.
First charge of iron	4,500 lb.
First charge of coke	200 lb.
Second charge of iron	2,500 lb.
Second charge of coke	200 lb.
Third charge of iron	2,500 lb.
Third charge of coke	200 lb.
Fourth charge of iron	2,500 lb.

SIX CHARGES MORE, CONTINUED PER ORDER SHOWN.

No. 8 Sturtevant fan; diameter of main blast pipe	12 in.
Time of starting fire	12.00 A. M.
Time charging first iron	1.30 P. M.
Blast put on	2.50 P. M.
First appearance of fluid iron	3.00 P. M.
Bottom dropped	4.50 P. M.

Revolutions of blower, 2,200; pressure of blast, 9 to 11 ounces: kind of fuel used, Connellsville coke; kind of flux used, limestone or oyster shells.

TOTALS.

Amount of iron melted	27,000 lb.
Amount of fuel consumed	3,200 lb.
Ratio of fuel to iron used	1 to $8\frac{44}{100}$
Fluidity of melted iron	Medium
Length of heat	2 hours

REMARKS.—The class of work made was heavy steam and blast engines and machinery.

DETERMINING FRICTION LOADS UNDER VARIOUS CONDITIONS

W. H. WAKEMAN

AN EXPLANATION OF INDICATOR DIAGRAMS TAKEN FOR THE PURPOSE OF LOCATING THE CAUSE FOR AN OVERLOAD ON A CORLISS ENGINE

THE following diagrams were taken from an overloaded Corliss engine, for the purpose of determining whether it was possible to reduce the friction load enough to avoid providing more power to run the same number of machines. They are not presented on account of perfection of outline in themselves, nor to show extraordinary conditions in the engine from which they were taken, but as a lesson for the benefit of those who are not familiar with this work, as they were secured under ordinary working conditions, and are presented just as they appeared when taken.

This engine is fitted up in a very convenient, but rather peculiar way, as the flywheel carries two belts which transmit power in opposite directions, to two friction clutch pulleys on the jack-shafts, so that by throwing out these clutches, only the engine and two loose pulleys will run. Diagrams taken under these conditions are said to represent the friction load of the engine, and this is approximately correct.

The diameter of the piston of this engine is 16 inches, giving an area of 201 square inches, and the diameter of the piston rod is $2\frac{3}{8}$ inches, giving an area of 4.43 square inches. When one-half of the latter is subtracted from the former, it shows that the effective area is 198.79 square inches, as steam pressure cannot act on space occupied by the rod, and as it acts on only one side of the piston at a time, one-half of its area is taken from the area of a 16-inch circle.

The stroke is 3 feet and the flywheel

revolves 66 times per minute; therefore the piston speed is 396 feet.

The horsepower constant of an engine is the power developed for 1 pound of mean effective pressure acting on the piston.

It is found by multiplying the effective area of piston, by the piston speed and dividing the product by 33,000. In this case it is $198.79 \times 296 \div 33{,}000 = 2.385$.

Having found this constant we multiply it by the mean effective pressure of a pair of diagrams, and the product is the horsepower developed for those conditions.

Fig. 1 is a pair of diagrams taken when the shafting was at rest. They show a very uneven cut-off, but were submitted by the engineer in charge as representing average conditions. The paper was fastened to the board of a Coffin planimeter, and with the vernier at zero, the tracer was placed at the highest part of diagram from the crank end. After it had been run over the lines of this diagram, in the direction traveled by the hands of a watch until it returned to the starting point, and then carried up vertically until the vernier returned to zero, its position was marked on the paper.

There was a No. 40 spring in the indicator when these diagrams were taken; therefore a No. 40 scale was used

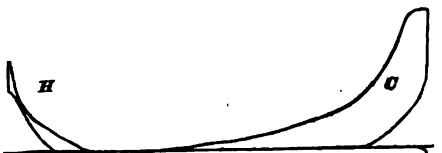


Fig. 1

to measure from the starting point to the final point reached, and the mean effective pressure so obtained was 7.5 pounds.

Placing the tracer at the extreme right of the diagram from the head end, and the vernier at zero as before, the tracer was run over the counter pressure line, and up the compression curve to the highest part of diagram; then

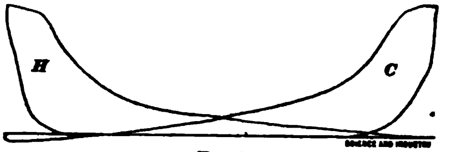


Fig. 2

down the expansion line to the starting point. The vernier now indicated a negative area, because the loop below the atmospheric line is greater than the area of diagram above it. This made it necessary to bring the tracer downwards (instead of upwards) until the vernier returned to zero.

Measuring between the two points, as before, with a No. 40 scale indicated 4.5 pounds mean effective negative, or back pressure. Subtracting this from the mean effective pressure of the crank end, leaves 3 pounds effective pressure for one stroke only during each revolution, assuming these conditions to remain constant.

Dividing this by 2 shows that the mean effective pressure for both diagrams is 1.5 pounds. Then, $2.385 \times 1.5 = 3.58$ horsepower developed by the engine, with the shafting at rest.

This shop is divided into two departments of nearly equal size, which will be designated No. 1 and No. 2.

The clutch controlling the machinery in No. 1 was thrown in, and the diagrams shown in Fig. 2 were secured. The mean effective pressure of the head end is 13 and of the crank end 11.5 pounds, or 12.25 for both; therefore, when they were taken, $2.385 \times 12.25 = 29.22$ horsepower was developed. Subtracting the power required to run the engine, demonstrates that it requires 25.64 horsepower to

run the shafting in department No. 1.

This clutch was thrown out and No. 2 thrown in, when the diagrams shown in Fig. 3 were secured. The mean effective pressure of the head end is 12

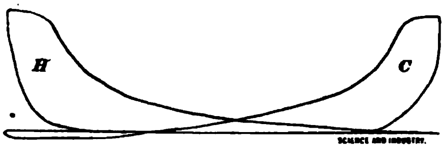


FIG. 3

pounds and of crank end 10.5, or 11.25 pounds for both.

Then, 2.385 × 11.25 = 26.83 horsepower developed under these conditions. Subtracting the power requird to run the engine, demonstrates that it takes 26.83 — 3.58 = 23.25 horsepower to run the shafting in department No. 2.

Having determined the power required to turn the shafting in each department separately, we may find the whole by adding them together, and 25.64 + 23.25 = 48.89 horsepower.

Special attention is called to this point because I find that some engineers consider this rule incorrect because, it calls for subtracting the friction load of the engine twice, which appears to be a mistake. This should be deducted twice because, it was two separate tests, the same as if two engines were used and they were located in different shops.

Both clutches were then thrown in

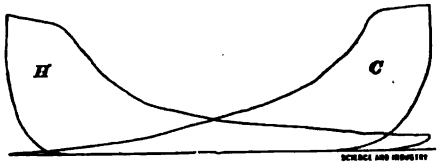


FIG. 4

and the diagrams illustrated in Fig. 4 taken. The mean effective pressure for the head end is 22 and for crank end 20 pounds, or 21 for both. 2.385 × 21 = 50.08 horsepower under these conditions. Here it is proper to subtract the friction load of engine only once, because it is one test of two departments together. 50.08 — 3.58 = 46.50 horsepower required to turn the shafting in both departments.

This result differs slightly from that secured by adding the two together, as there is 2.39 horsepower more in one one case than in the other. This is not due to a difference in calculation, but to some slight change in the load making a difference of 1 pound in the mean effective pressure.

Theoretically, the power developed should be the same in both cases, but in practice it would be difficult or impossible to attain this result, owing to small changes in conditions, for although an engine may make the same number of revolutions per minute during two tests, yet it seldom travels

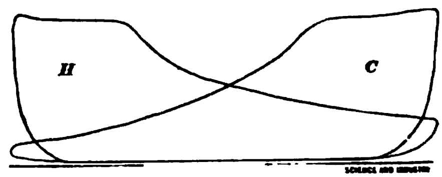


FIG. 5

at the same rate during a whole minute, and these small variations effect the mean effective pressure for each diagram, as it is taken in about 1 second.

Fig. 5 was taken with an average load, as machines in both departments were in operation.

The mean effective pressure of the head end is 38 and of the crank end 36 pounds, making it 37 for both. Then, 2.385 × 37 = 88.24 horsepower developed. The diagrams shown in Fig. 5 have nothing to do with the friction load, but they do enable us to determine how much power is used in driving the machines. By subtracting the power developed when Fig. 4 was taken we find that

88.24 — 50.08 = 38.16 horsepower is the effective load in this case.

This comparsion provides an item of interest, because it requires more power to turn shafting than it does to drive the machines, as the latter is but 43 per cent. of the full load.

The excessive friction load shown in Fig. 4 is not due to faults in the engine, as its frictional load is but 4 per cent. of the full load, as demonstrated by Figs. 4 and 5; therefore it must be in the shafting. Some of it is probably due to lack of alinement in the boxes, but much of it may be charged to distribution of machines over a large area, calling for long lines of shafting to transmit power to them. Crossed belts add to the friction and shafts set at an angle of 30° or 40° to one another, do not turn as easily as they would under other conditions.

Excessive friction loads in shops like this give the manufacturer of small engines a chance to show the advantage gained by locating several specimens of his product in different departments, thus doing away with long lines of shafting, but this plan is not always successful as small engines are not economical in the use of steam when new, and are less efficient after they have run several years.

Electric motors can be utilized as it is practical to start and stop them at pleasure. It is much cheaper to run a wire to a machine than to carry a long line of shafting for the purpose of driving it, and when the machine is not in use the current is shut off and there is no shaft to turn. The cost of changing from shafting to electric motors is heavy; therefore many shops are run under unfavorable conditions, but when fitting up a new shop, plans should be made whereby the friction load will be light.

What plan to adopt in this particular case has not been determined, further than to line up the shafting, and to provide the best oil for lubrication. Roller bearings may be put in to reduce the friction to a minimum.

DRESSINGS FOR BELTS

A CHEAP and effective dressing for a belt is tallow. When a belt is pliable, and only dry and husky, the application of blood-warm tallow, thoroughly dried in by the heat of the sun or fire, will tend to keep the belt in good working condition. The oil of the tallow passes into the leather, serving to soften it, and the stearin is left on the outside, to fill the pores and leave a smooth surface. The addition of resin to the tallow for belts, if used in wet or damp places, will be of service and help preserve their strength. Belts which have become dry and hard should have an application of neatsfoot or liver oil mixed with a small quantity of resin. This prevents the oil from injuring the belt and helps to preserve it. There should not be so much resin as to leave the belt sticky. Belts should not be soaked in water before oiling, and penetrating oils should but seldom be used, except occasionally when a belt becomes very dry and hard. It may then be moistened a little and have neatsfoot oil applied. For new belts a composition of tallow and oil, with a little resin or beeswax, should be used.

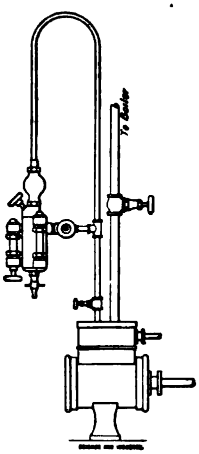
Prepared castor oil dressing is good and may be applied with a brush or rag while the belt is running. Belt dressings of any kind must not be applied too liberally in the case of a new belt, otherwise it is apt to stretch, making it very liable to run out of line.—Power and Transmission.

USEFUL IDEAS

PIPING A LUBRICATOR

I submit the following sketch for the "Useful Ideas" column of SCIENCE AND INDUSTRY:

The sketch represents a method of



piping a lubricator to a steam feed pump. As ordinarily piped every time the speed of the pump is changed the feed of the oil in the lubricator is changed. If the pump is run slower the feed of oil is increased and vice versa, also, if the pump is stopped before the lubricator is closed all the oil in the lubricator is injected into the pump. With this method of piping these troubles are remedied.

ELECTRICAL NOTES

J. S. Gibbs, Beaumont, Texas

I desire to contribute an article or two to the "Useful Idea" Department of SCIENCE AND INDUSTRY, which I hope will be of use to some of the readers.

Having had a little experience lately with alternating-current apparatus, I offer a few points in regard to testing and remedying trouble with fan motors. In small alternating-current fan motors after running a season or so the shaft and boxes commence to wear, developing enough friction to cause them to run slow and to impede the starting of them when the current is turned on. As the fans run on a 125-cycle circuit, they have 8 poles which makes them rotate at a speed of a little less than two thousand revolutions per minute, allowing for the slip. By cutting out of circuit one of the fields and killing the pole piece, only 7 coils are left in circuit, thereby decreasing the resistance and allowing a little more current to flow in the motor. Also, there being only 7 pole pieces in circuit the motor tends to rotate at a higher speed to keep in step with the frequency of the alternator. After trying this several times I finally got a number of motors to operate at proper speed without any excess heating.

Perhaps it would be of interest to know that I also run 104-volt fans on 52-volt circuits by putting the field coils in multiple, reducing the resistance in both halves of the circuit and have a number of them operating on the circuit. To test these fans I only had a 104-volt circuit, but ran a third wire to the pole, tapping between the two secondary coils of the transformer and drawing 52 volts from it. Recently I had some old style alternating-current motors to repair. They had commutators on them which were all cut up, and the friction of the brushes on them caused them to run slow. I now run them as induction motors, taking the brushes out and closing the circuit, leaving only the fields in. By turning the current on and just giving them a start by hand they immediately pick right up and will run for 12 hours at a time without heating.

EDITORIAL COMMENT

The supplement issued with this number contains a table of dimensions of standard keyways and should, we think, be of considerable use to draftsmen and designers who have not already a table of this kind to refer to.

We have received the following letter from James L. Robertson & Sons with the request that it be published:

NEW YORK, March 8, 1902.

Editor Science and Industry,
Scranton, Pa.:

DEAR SIR.—In your issue of March, 1902, we notice a letter from the Union Steam Specialty Co., criticising the article by Mr. G. H. Waltman, in which the improved Robertson-Thompson Indicator was fully described and appearing in your issue of November, 1901.

They claim that the Improved Robertson-Thompson Indicator, is an infringement of patents held by them, and notify the public and prospective purchasers in a very *mild and pathetic* way—that they are liable for an action to recover damages and royalties.

As manufacturers of the Improved Robertson-Thompson Indicator, we feel that in justice to the many persons now using our instrument and prospective purchasers—to simply state, that if the Union Steam Specialty Co. have any grounds for the claims they are making, the United States Courts furnish them ample opportunity to protect their rights.

We beg to ask that you give this as prominent space in your paper as the letter alluded to occupied.

Respectfully yours,
(Signed) JAMES L. ROBERTSON & SONS.

Forty years ago very low pressure was ordinarily employed for engines with condensers, while what was considered a very high pressure was adoped for engines that exhausted into the atmosphere. Hence arose the terms high and low pressure engines, the former being engines with, and the latter without, condensers. At present, a high pressure of steam is ordinarily carried in both kinds of engines, so that the terms do not describe the two varieties as well as formerly. Many engineers prefer to class engines as condensing and non-condensing, rather than as high and low pressure; and this classification is generally considered the more correct of the two. One who regards economy puts in a condensing engine, if he has plenty of water in the locality; and many old non-condensing engines are being fitted with condensers, under the more enlightened engineering practice of the present time.

It may be fairly assumed that a non-condensing engine has, on an average, at least 2 pounds per square inch back pressure on the piston. By the application of a condenser, it might be expected that there would be a negative pressure of 10 pounds per square inch on the back of the piston, so that the piston pressure would be increased by 12 pounds. In this assumption, an allowance is made for the power required to work the air pump, and the engine is supposed to be at least 75 horsepower. For an engine smaller than this, it would be better to allow an increase in the positive pressure of not more than 10 pounds per square inch. As the condenser, by decreasing the back pressure on the piston, adds just as much to the positive pressure, it is plain that a lower pressure of steam can be used, or the steam may be cut off at an earlier point of the stroke. The gain in either case can be approximately calculated. If the gain in positive pressure produced by the reduction in back pressure be multiplied by 100, and divided by the mean effective pressure on the piston, it will give the percentage of gain in pressure due to the condenser.

Thus, if the mean effective pressure on the piston is 30 pounds per square inch, the gain in pressure will be 100 times 12, or 1,200, divided by 30, which is 40 per cent. Now suppose that before the condenser was attached, the steam was cut off in the cylinder at half stroke; under the new conditions the required mean effective pressure can be obtained with a lower boiler pressure than before. Before the condenser was in use, it would be necessary to maintain a pressure in the boiler of about 58 pounds per square inch by gauge, to give a mean effective pressure of 30 pounds on the piston; while with an increase of 12 pounds in the effective pressure, by the application of the condenser, a boiler pressure of about 39 pounds would suffice. As the weight of steam per cubic foot at 58 pounds pressure is 0.17481 pounds, and only 0.132 pounds at 39 pounds pressure, there would be a saving of about 24.5 per cent. in the amount of steam required to run the engine. Instead of reducing the steam pressure after attaching a condenser to an engine, it might be better to maintain the same pressure in the boiler, and cut off the steam at an earlier part of the stroke. In the case under consideration, the increase of 12 pounds in the effective pressure would permit of closing the steam port a little before the completion of one-third of the stroke; and supposing that the clearance space in the cylinder amounts to 5 per cent. of the capacity of the cylinder, the quantities of steam required per stroke, before and after the use of the condenser, would be in the ratio of 550 to 363, so that there would be a saving of 34 per cent.

The example given represents a case in ordinary practice. By varying the data, of course a greater or less amount of saving would result; but with an engine in good condition, it is generally safe to estimate that a saving from 20 to 25 per cent. of the amount of steam used, and, consequently, of the consumption of coal, will be realized by the application of a condenser. Indeed, it is not unusual for manufacturers to guarantee this amount of saving, in converting a non-condensing into a condensing engine.

BOOK NOTICES, CATALOGUES, AND TRADE NOTES

On the Composition of Dutch Butter. By J. J. L. van Ryn, Director to the Royal Agricultural Experimental Station at Maastricht. Bailliere, Trindall & Cox, London, 1902.

Butter is one of the chief agricultural articles of export of Holland, and has always found a ready market in England. During the last few years every fall or winter quantities of Dutch butter have been rejected, English chemists having declared them to be mixtures of butter and margarine. Mr. van Ryn made a very careful and exhausting study of the subject for the Dutch Government, and found that the condition of feeding, pasturing, or stabling had a very important influence on the general character of the butter. He points out that the abnormal conditions which led to the rejection of the butter, and which, on chemical analysis, were considered as indications of adulterations, were entirely due to advance of lactation, food, environment, etc. The book is of great interest to agricultural and food chemists.

The Soap Brand Record and Trade Mark Manual. By Leebert Lloyd Lamborn, B. S., B. S. Published by Chas S. Berriman, New York. Price $5.00.

Both Mr. Lamborn and Mr. Berriman are well-known among soap manufacturers, the former as a chemist and the latter as the publisher and editor of the "Soap Gazette and Perfumer," and both appear to be eminently fitted to bring some light into the chaos of trade marks, soap brands, etc. The book consists of three parts. Part I contains the definition and origin of trade

marks, classification of trade-mark laws, United States and foreign trade-mark laws, registration of trade marks, digest of prominent decisions in trade-mark cases, etc. Part II contains a list of copyrighted trade marks, and Part III, a list of soap firms and of trade marks, copyrighted and uncopyrighted, in present use and claimed ownership by the soap manufacturers reporting. The book is well printed and bound, and can be recommended to every soap manufacturer and every one interested in trade marks, etc.

LETTERING FOR BEGINNERS. By John T. Parson, Instructor College of Civil Engineering, Cornell University, Ithica, N. Y. Published by the author. Price 65 cents.

This little book consists of a large number of model alphabets illustrating the different styles of lettering and is designed for the use of students in drawing. It is very well gotten up and will admirably fill the purpose for which it is intended.

ENGINEERING PRACTICE AND THEORY. By W. H. Wakeman, 64 Henry St., New Haven, Conn. Published by the author. Price $1.00.

This is the second edition of a book that was favorably commented on in these columns when it first appeared. It contains 184 5 × 7½-inch pages, with numerous illustrations, and is bound in stiff-cloth covers. Steam engineers will find it a useful and profitable book, as in it are given the ideas of an engineer who has an intimate knowledge of the subject.

EASY LESSONS IN MECHANICAL DRAWING AND MACHINE DESIGN, Part 20. By J. G. A. Meyer. Published by the Industrial Publication Co., New York.

We are in receipt of Circular No. 65, and Bulletin No. 28, of the Northern Electrical Mfg. Co., of Madison, Wis., describing the Watson Multipolar Motors and Generators, manufactured by the Mechanical Appliance Co., of Milwaukee. This concern has devoted itself exclusively to the design and manufacture of small motors and generators, and their machines contain a number of novel features not to be found in any other. The motors and generators vary in size from ⅛ to 2 H. P., and from $\frac{1}{10}$ to 1½ K. W., respectively. The chief departure from the old-style machine is achieved by making them multipolar instead of bipolar, as was formerly done. The armatures are so wound as to secure thorough ventilation, which is a very desirable feature. Their dust-proof motors, being entirely enclosed by removable caps, are very desirable under certain conditions. Among the specialties manufactured by this concern are a special linotype motor, arranged for either belt or gear drive, a motor direct connected to a forge blower, and a motor direct connected to a ventilating fan. They also turn out a motor with a magnetic-brake attachment, which is as yet a comparatively new device on the market.

The Armstrong Bros. Tool Co., 617–621 Austin Ave., Chicago, Ill., have sent us their latest catalogue. It is neatly gotten up, and gives descriptions, illustrations, and prices of the machine shop specialties manufactured by them.

The Eastwood Wire Mfg. Co., Bellville, N. J., has gotten out a neat little catalogue descriptive of the engineering specialties manufactured by them. It also includes several useful tables for reference.

The Rensselaer Polytechnic Institute of Troy, N. Y., founded by Stephen Van Rensselaer in 1824, was the first engineering school established in any English-speaking country. The circular deals especially with the course in Electrical Engineering as now given at the Institute and shows it to be thorough and complete in all branches.

We have received the special Pan-American catalogue of the Chicago House Wrecking Co., Chicago, Ill. This concern has purchased the buildings of all the large expositions and after dismanteling them sells the material. The catalogue contains a list of the miscellaneous material used in the construction of the Pan-American Exposition buildings which can be purchased at much less cost than new material.

We are advised that the Penberthy Injector Co., of Detroit, Mich., has become reestablished, since their plant was wrecked by a boiler explosion last fall, and is now working day and night to keep up with the demand for Penberthy injectors. The jury empanelled to determine the cause of the explosion has exonerated the company and its employes from blame. They found that the explosion was due to poor material and workmanship in constructing the boiler. The explosion occurred on Nov. 26, 1901 and resulted in the death of thirty persons.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

MECHANICAL

(126) With a given contact pressure, what is the force required to cause motion between (*a*) two smooth iron surfaces, one fixed and the other revolving; (*b*) a smooth iron surface and a hard wood surface? (*c*) What wood used in contact with iron will oppose the most frictional resistance?

L. L. D., Carlisle, Pa.

ANS.—The ratio between the contact pressure and the force mentioned (which ratio is called the coefficient of friction) depends on the speed and many other conditions, as shown in recent articles on the subject. When the loads are light, say 30 or 40 pounds per square inch, and the surfaces are smooth and clean, but unlubricated, the value for cast iron on cast iron will be about one-sixth; rather more on wrought iron; less on steel, and still less on brass. The coefficient for steel on brass is about one-seventh. Brass or bronze in contact with steel or iron gives a low friction, and on tin a high one. Brass on brass, and tin on tin engender considerable friction. Various anti-friction metals, composed of tin, lead, and copper, and sometimes zinc and antimony, are employed, which reduce the friction more or less. Such a one, known as Magnolia metal, is a good example. (*b*) and (*c*) This depends on the nature of the wood. On an average, the coefficient will be from one-fourth to two-fifths. Oak appears to give as high a frictional resistance as any.

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(127) Please enumerate the common types of locomotive at present in use and mention their distinguishing features, and also those of such special types as the Atlantic, Chautauqua, Prairie, and Mountain.

F. W. H., Pittsburg, Pa.

ANS.—The eight-wheeler, or American type, having a four-wheeled truck and four drivers; the mogul, with a two-wheeled truck and six drivers; the consolidation, with a two-wheeled truck and eight drivers; the ten-wheeler, with a four-wheeled truck and six drivers; the decapod, with a two-wheeled truck and ten drivers; and the twelve-wheeler, or mastodon, with a four-wheeled truck and eight drivers. The other common types include those used for switching and suburban traffic. The special types are many, and consist chiefly of variations in the design of firebox and the arrangement of wheels. The greatest innovation ever made in locomotive practice, so far as appearance goes, was in putting the cab midway along the boiler, the result of using the "wide" firebox—for the purpose of burning slack and culm. This was first done in freight engines, the small wheels permitting the box to be carried out over them without perching the boiler unduly high or curtailing its depth; although, as a matter of fact, only a shallow box was required for the small coal this arrangement was intended for. Latterly the wide box has been more generally adopted, regardless of the fuel, and where the wheels were large (as in fast passenger work) a limit was reached where the depth of firebox could not be attained with the boiler center kept within proper limits. So the rear drivers were moved forward and a small pair of trailing "carrying" wheels employed. Among these engines are the following classes: *Atlantic*, four-wheeler truck, four drivers, and pair of trailers; *Columbia*, two-wheeler truck, four drivers, and a pair of trailers; *Chautauqua*, same as Atlantic, and having a wide firebox; *Prairie* and *Lake Shore*, same wheels as *Columbia*, and with a wide firebox; *Northwestern*, same as Chautauqua; *St. Paul* type, same wheels as a Consolidation, plus a pair of trailers, and a wide firebox. We are not familiar with any type called the *Mountain*.

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(128) (*a*) Would it be possible to pump

water into a boiler with an injector, using compressed air instead of steam, providing the air had a temperature of 300°? (*b*) What is the average back pressure in a simple locomotive, using a heavy forced draft? (*c*) What is it in a compound locomotive? W. F. S., Onward, Ind.

ANS.—(*a*) No. An injector can not be made to force water into a boiler when compressed air is used to operate it, even though the air be heated to a high temperature. An injector can be operated only by the use of a gaseous fluid that is *condensable*, since the principle of operation of the injector depends upon the expansion and *condensation* of the gaseous fluid within the combining tube of the injector. An ejector, on the other hand, can be operated either by air, steam, or water, since its principle of operation does not depend on the condensability of the operating fluid. (*b*) and (*c*) It is very difficult because of the varying conditions, such as speed, etc., to give the actual back pressure in either type of engine. However, when both types of engines are in good condition, the back pressure in the low-pressure cylinder of the compound engine will probably be about 25% lower than the back pressure in an equivalent single-expansion engine. The back pressure in simple engines will probably vary from 8 to 15 pounds under average working conditions in passenger service, while the back pressure in the low-pressure cylinder of a compound engine will vary from 6 to 12 pounds under similar conditions in passenger service. In freight service with very heavy trains, the back pressure line in both types of engines will follow the atmospheric line quite closely, provided the parts of the engine are properly proportioned and the draft appliances properly adjusted.

***

(129) (*a*) Please give me the formula for calculating the horsepower of a locomotive. (*b*) How can you determine the tonnage a locomotive will haul? (*c*) How much more fuel will a locomotive with ¼″ of scale on the tubes use than one with clean tubes? F. E. P., Bucyrus, Ohio.

ANS.—(*a*) The formula for calculating the horsepower developed by a locomotive is as follows: $\text{H. P.} = \frac{P \times 2L \times A \times N \times 2}{33{,}000}$; where $P =$ the mean effective pressure in pounds per square inch acting on the piston (which can be estimated as two-thirds the boiler pressure); $L =$ the length of the stroke in feet; $A =$ the area of the piston in square inches; $N =$ the number of revolutions per minute made by the drivers. The horsepower of a locomotive is a quantity seldom required. The tractive power, however, which is a measure of the adhesion of the wheels to the rail is a very important factor. This is calculated by the following formula: $\text{T. P.} = \frac{P \times D^2 \times L}{d}$; where $P =$ the mean effective pressure in pounds per square inch acting on the piston; $D =$ the diameter of the piston in inches; $L =$ the length of the stroke in feet; $d =$ the diameter of the drivers in feet (where there is more than one size of driver use the smallest). This formula gives the tractive power in pounds. (*b*) The rule for calculating the load which a locomotive will haul on a level track is as follows: Divide the tractive power by the resistance in pounds per ton due to friction, imperfection of road, wind, etc. This may be roughly estimated at 7½ lb. per ton. The quotient is the total load inclusive of engine and tender which the locomotive can haul. (*c*) Experiments performed to determine the effect of scale on the economy of boilers indicate that with a layer of scale $\frac{1}{16}$″ thick on the heating surface about 15 per cent. more coal must be used than with a clean heating surface, while with thicker layers of scale a proportionately larger amount of coal must be used. This would indicate that with ¼″ of scale on the entire heating surface the locomotive would burn 60% more coal than if the tubes were clean. This may seem rather large, but will, we think, pretty closely approximate actual conditions.

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(130) What conditions are necessary for the successful operation of a hydraulic ram? F. M., Grantsville, Utah.

ANS.—See article, "The Hydraulic Ram," in the April, 1896, issue of Home Study, a copy of which magazine you can obtain for 15 cents from the International Textbook Company, Scranton, Pa.

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(131) I have an engine of the following description: Cylinder 24 × 48 inches, Corliss valve motion, double reel link motion, engine hoisting counterbalance from depth of 2,000 feet. When wishing to stop, is there any harm in reversing the engine and opening the throttle when using steam at boiler pressure, say 140 pounds, or would it be better to just reverse the engine and let the steam compress until it stops? H. C. L., Victor, Colo.

ANS.—We think, and believe most engineers will agree with us, that it is better to bring the engine to a gradual stop by reversing and keeping the throttle shut. The stresses on the engine are not as great then as when the engine is brought to a stop by reversing and opening the throttle.

***

(132) (*a*) I have been told that all good sized trucks are 6 inches higher in front than in the back, thus allowing the wagon to run easier. It seems to me that to run

easier that they ought to be higher in the back. (*b*) Will not a bob go faster on the snow if the back is higher than the front?
W. F., Carlstadt, N. J.

ANS.—(*a*) The height of the ends will make no difference in the ease with which the truck runs, except as it may affect the diameters of the wheels. The greater the diameters of the wheels, however, the easier the truck will run. (*b*) No. It will simply throw a slightly larger proportion of the weight upon the front runners.

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(133) Please give me a full description of the working of the valves of a steam hammer. I wish to build a hammer of about 300 or 400 pounds.
W. T. T., Oklahoma Ter.

ANS.—See "Engineering" (London) of November 15, 1901, page 691, for illustration of the valve mechanism of a steam hammer, and the method of operating it.

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(134) (*a*) What horsepower will be developed by a vertical waterwheel, operated by a stream from a 9-inch pipe which drops about 15 feet in 100? (*b*) Can you tell me where I can get a wheel suitable for this purpose, or what book will give me information on building such a wheel? (*c*) What is a microfarad? (*d*) How many hours can the plates of a storage battery be used before they will have to be discarded?
W. G. L., Barton, Md.

ANS.—(*a*) The theoretical horsepower furnished by water delivered under a given pressure can be calculated approximately by the following formula, H. P. = .022147 $a\sqrt{p^3}$; where a = the area of the discharging outlet in square inches and p = the pressure of the water in pounds per square inch. Inasmuch as you do not give the total length of the line, it is impossible for us to calculate the pressure, but you can probably do that yourself. The efficiency of a waterwheel is a variable quantity, depending on the type of wheel, etc. It may be roughly estimated at 50 per cent. That is, your waterwheel would develop about one-half the horsepower delivered at the end of the pipe. (*b*) Correspond with any concern building heavy machinery. (*c*) A microfarad is the one-millionth part of a farad. A farad is the unit of electrical capacity. For purposes of measurement, capacities of conductors are compared with those of condensers whose capacities are known in microfarads, or fractions thereof. The microfarad, or the $\frac{1}{1000000}$ of a farad, is used because of the very great size of a farad. (*d*) It is impossible to give a satisfactory answer to this question. The length of time which the plates of a storage battery can be used before being discarded varies greatly, depending on a large number of conditions.

ELECTRICAL

(136) (*a*) How are the ampere turns, required to force a given number of magnetic lines of force through the air gaps or spaces in Figs. 1 and 2, calculated? (*b*) How can the currents be calculated in the different circuits shown in Figs. 3 and 4? (*c*) Why is 2π used in formulas for calculating inductance and static capacity of circuits? (*d*) Please explain the principle of the storm glass. C. E., Chicago.

ANS.—(*a*) Let N be the total number of lines that you desire to force through the whole air gap in Fig. 1. Find the average cross section $a\,b$ by adding together the area of the two pole faces and dividing the sum by 2. Suppose this is S square inches. Then the average induction or density in the air gap $= \frac{N}{S}$. The ampere turns required to produce a given density $\left(\frac{N}{S}\right)$ in the air gap $= .3192 \times \frac{N}{S} \times l$; in which l is the length of the air gap in inches. In Fig. 2 it is practically impossible to calculate any average density of the lines of force in the path through the air; hence no calculations for the ampere turns required to force a given number of lines through the air can be made.

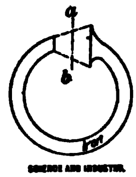


FIG. 1

(*b*) You have said nothing about the internal resistance of the batteries. Let us consider the most general case and let the electromotive force, current, and resistance in each branch have the values indicated by the letters placed on the figures. For Fig. 3 we can write the following three equations: $C_1 = \frac{(E - CR) - E_1}{R_1}$, $C_2 = \frac{E - CR}{R_2}$, and $C_1 + C_2 = C$. If we know the values for E, E_1, R, R_1, and R_2 we can solve these three equations for C, C_1, and C_2. For Fig. 4 we have $\frac{(E - CR) + E_2}{R_1} = C_1$, $\frac{E - CR}{R_2} = C_2$ and $C_1 + C_2 = C$. The values of C, C_1, and C_2 can be obtained by the simultaneous solution of the three equations in each case. In each case R is the total resistance of the circuit $a\,f\,g\,b$, R_1 the resistance from a to b and R_2 the resistance of $a\,d\,e\,b$.

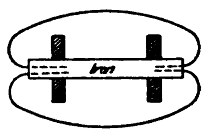


FIG. 2

(*c*) We presume you mean why does 2π occur in formulas for calculating the impedance of a circuit containing inductance or capacity in

addition to resistance. The formulas are $\sqrt{R^2 + W^2 L^2}$ and $\sqrt{R^2 + \frac{1}{C^2 W^2}}$; L being the inductance, C the capacity, and $W = 2\pi n$, in which n is the frequency of alternations or the number of complete cycles per second. These formulas depend upon the fact that the electromotive force and current are assumed to vary harmonically, that is to follow a sine curve, and this curve is derived from the uniform motion of a point in the circumference of a circle.

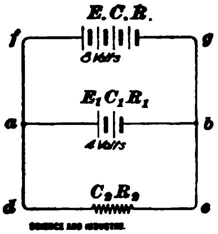


FIG. 3

When the point makes one complete rotation it has passed over a circumference $2\pi r$ in length. Assuming $r = 1$, the point has a velocity of 2π if it makes one complete rotation in 1 second. Evidently if it makes n complete rotations or cycles per second its velocity $= 2\pi n$. We cannot give here the complete derivation of the formulas for the impedance of a circuit possessing inductance or capacity. We will refer you for that to some book on alternating currents, such as "Alternating Currents," by Franklin and Williamson. You can obtain this book from the Technical Supply Co., price $2.

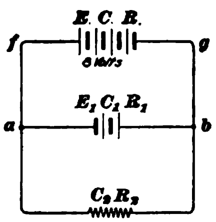


FIG. 4

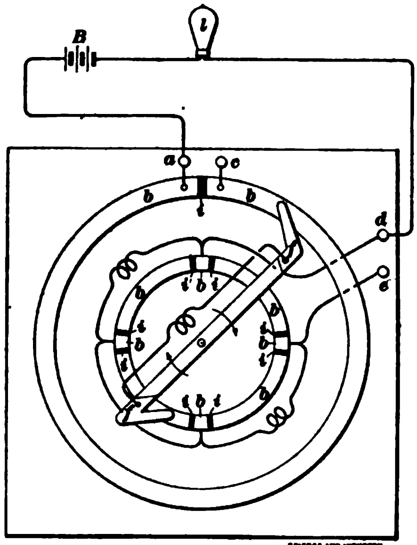
(*d*) The liquid consists of a solution of camphor, chloride of ammonia, and nitrate of potassium in alcohol and a little water. The chemicals are affected chiefly by heat and possibly in a slight degree by light and electrical disturbances. It is not considered as a reliable forcaster of the weather. It is possible that the chemicals are all dissolved at a certain temperature and pressure, and that when the pressure falls, as it does before storms, or the temperature falls, or both, that they are separated out of the solution giving the white precipitate that is supposed to predict a storm. If the temperature was always constant it would be more reliable if the explanation just given holds true.

***

(137) Please show how the rotating switch, illustrated in the accompanying sketch, may be connected to an incandescent lamp and battery, so that the lamp will light up when the inner brush *f* makes contact with the small brass pieces of the inner ring, and the lamp will be dark, when the inner brush *f* makes contact with the large brass pieces on the inner ring. There are two contact rings, an outer and an inner. The parts marked *b* are made of brass; the parts *i*, of fibre. The outer ring is connected to binding posts *a* and *c*. The four small pieces of brass on the inner ring are connected to binding posts *d* and *e*. The four large pieces of brass on the inner ring are not connected. Brushes *f* and *f*, which are connected together, are made of brass and are mounted on the fibre-rotating arm.

J. L. P., Pittsburg, Pa.

ANS.—The desired result may be obtained by connecting one terminal of the battery to binding post *a*, the other battery terminal



to one terminal of the lamp *l* and the other terminal of the lamp to binding post *d*. With this simple arrangement binding posts *c* and *e* need not be used. When the inner brush touches any one of the four small brass pieces on the inner ring the lamp will light up. When the inner brush is on the large brass pieces, the lamp will be dark.

***

(138) What are the front and back pitches for a 4-pole armature, wound as follows: 43 coils placed in two layers on a 43-slot armature, the commutator having 86 bars, one-half of which are used for the armature leads and the other half cross-connected to opposite bars; a bar having armature leads connected to it is cross-connected with the bar exactly opposite, which does not have armature leads connected to it; 4 sets of brushes, 90° apart, are used on the commutator; the armature is wound for 220 volts?

T. Y., Philadelphia, Pa.

ANS.—The data is not complete, but we

presume that this is a wave-wound interpolated segment armature. Call the top half of one slot, No. 1 winding space; the bottom half, No. 2 winding space; the top of the adjacent slot, No. 3 winding space; the bottom of this slot, No. 4 winding space. Number in this way all around the armature. There will then be 86 winding spaces. A front pitch of + 21 winding spaces and a back pitch of + 21 winding spaces can be used in connecting up the coils. If one side of a coil is placed in winding space 86, which is the bottom half of a slot, the other side of this coil goes into winding space 21, which is the top half of slot No. 11. Connect the lead of the side of the coil which is in winding space No. 86 to bar No. 75, and the other lead of the coil to bar No. 31. Continue in this manner. Bar No. 1 is in line with slot No. 1, and the bars are numbered around the commutator in the same manner as the winding spaces are numbered. In connecting to the commutator, connect armature leads into every alternate commutator bar. This leaves an unused bar between any two bars to which armature leads are connected. These unused bars are connected to bars directly opposite, which bars hold armature leads. Either 4 sets of brushes, 90° apart, or 2 sets of brushes, 90° apart, can be used in connection with this armature. Four sets would probably be used to facilitate the passage of current between the commutator and the brushes.

***

(139) I have in my house, which is one-fourth mile from the telephone exchange, a telephone that roars like a telegraph wire in a small railway station. There is no other telephone between my house and the central office. The last part of the wire is not very tight.

W. K. S., Wayland, Iowa.

Ans.—When you say it roars like a telegraph wire in a small railway station, we hardly know whether you mean that it repeats the clicking of the telegraph instruments or merely roars like the line wires near the station. If it repeats the clicks of the telegraph instruments it is due to one of two causes: either your line wire runs parallel and probably on the same poles with the telegraph wires, in which case the trouble is due to induction, or else there is poor insulation at one or more points between your line and the telegraph line. In the former case you should use a complete metallic circuit (2 wires, 1 each way) and transpose them frequently or move your wire or wires further away from the telegraph wires. In the latter case you must insulate your wires better. It is possible if you use a ground return that your wire is not well enough grounded. To remedy this use a ground plate of several square feet of sheet copper, placed in earth that is always moist and below the freezing crust of the earth. If there are electric railroads in your neighborhood and you use a ground return, then your trouble is due to the railway current returning through your line. To remedy this you must use 2 line wires and no ground. Your wire being loose has nothing to do with the case, provided it is not so loose as to swing against other wires or touch anything except the insulators upon which it should only be supported.

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(140) Kindly let me know how cheap I could rig up an electric fan with 6-inch blades. How strong and how large will the batteries have to be? What kind of batteries must I use? J. S., Clinton, Ia.

Ans.—A motor to run a 6-inch fan would be quite small, and if you purchased the castings and finished them up yourself, you could probably build a motor for about $3. You can obtain castings for small motors from Parsell and Weed, 129 West 31st street, New York City, the Bubies Publishing Co., Lynn, Mass., or J. Elliott Shaw & Co., 632 Arch street, Philadelphia, Pa. You would require six or eight bichromate cells. The Fuller bichromate cell is a very good one for this purpose.

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(141) (*a*) Why do grounded telephone lines work better at one time than at another? There are no trolley or electric light circuits in the neighborhood. Sometimes in the morning or before a storm we can hear best. (*b*) Will grounding two lines through the same ground wire cause induction? (*c*) Is there any time when the earth is not a good conductor for an electric current? (*d*) Does the current flow from one ground wire to another the same as on the line of a grounded circuit?

M. R. C., Fitchburg, Mich.

Ans.—(*a*) Yes, grounded telephone lines may work better at one time than another if the ground plates or rods are not placed deep enough to be always in moist earth and below the portion of the earth's surface that freezes in winter. Dry earth and frozen earth are very poor conductors of electricity. When the ground plates are not properly placed the current from one line may be forced to return, if at all, through the other telephone line or lines that happen to be connected to the same ground plate or wire. Grounded circuits may talk better after a rain or snow, due to the fact that the ground is more moist. (*b*) No, it will not cause induction, but it produces practically the same effect, due to the fact that the current may find the other line a better conductor than the earth. It is not a good plan to ground two lines through the same ground wire or plate. Use entirely separate ground circuits and be sure that the ground plates or rods are deep enough

to be below the frost line and in moist earth. Dry or rocky ground usually forms a very poor place in which to place a ground plate or rod. (*c*) The conductivity of the earth's surface, especially for distances less than a mile apart, may vary considerably, due to its geological formation and to the amount of moisture present. (*d*) It is difficult to say what is meant by this question. The current will flow from one ground wire through the earth to another ground wire and will return through the second line instead of through the earth, if the second line offers less resistance than the earth. You will find the subject of induction and troubles on grounded telephone circuits very well treated in "Telephone Lines and Their Properties," by Hopkins. This is for sale by The Technical Supply Co., Scranton, Pa. Price $1.50.

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(142) Can you give me the names and addresses of telephone companies operating in the Philippine Islands or in South America?

A. B. C., Pittsburg, Pa.

ANS.—We have been unable to find the exact name or addresses of any telephone companies asked for. You might obtain the information desired by writing to United States consuls located in the principal cities in the Philippine Islands and in South America. The names of the consuls you could, doubtless, obtain from the Department of State at Washington, D. C.

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(143) (*a*) Please inform me as to the greatest carrying capacity, in volts and amperes, of No. 28 copper wire B. & S. gauge. (*b*) Give address of a reliable firm who furnish sheet-iron punchings for motor armatures.

F. D., Lyons, Mich.

ANS.—(*a*) The current that a wire will safely carry depends largely on where the wire is situated. If it is on a magnet spool where the winding is fairly deep and there is little chance for the heat to get away, it would not be safe to use a current much larger than .15 ampere. If it were on an armature where the ventilation was fairly good, it would carry twice this amount. The voltage that may be applied to a wire forming part of an electrical circuit depends upon the insulation of the wire, i. e., the voltage tends to break down the insulation either to ground or to the other side of the circuit, so that the voltage which the wire will stand does not depend on the size of the wire but on the thoroughness with which it is insulated. A wire does not carry voltage, it carries current, as a small wire can stand just as high voltage as a large one, provided it is equally well insulated. (*b*) Try Parsell and Weed, 129 West 31st street, New York City, J. Elliott Shaw & Co., 632 Arch St., Philadelphia, Pa., or the Bubier Publishing Co., Lynn, Mass.

MISCELLANEOUS

(144) (*a*) Please give me a short method for determining cadmium and bismuth in a sublimation product, containing about 50% arsenic, 5% sulphur, and 20% lead, and small percentages of silica, iron, zinc, and copper. (*b*) Can cadmium be determined by ferrocyanide titration method on the above, and what special care must be taken? (*c*) Will Pearce's method for arsenic give good results on this product? If not, please give me a good method for arsenic.

A. Z., Helena, Mont.

ANS.—(*a*) Dissolve about 1 gram of the substance in fuming nitric acid, adding the same drop by drop. After the acid has acted for some time in the cold, heat on the water bath until red fumes are no longer driven off, then remove the watch glass, wash any particles adhering to it back into the dish with as little water as possible and evaporate to dryness. Moisten the residue with concentrated hydrochloric acid and again evaporate to dryness. Add about 2 c. c. of concentrated hydrochloric acid and 50 c. c. of hot water, boil for a few minutes, allow the insoluble matter to settle, then filter and wash well with hot water. To the filtrate add an excess of sulphuric acid to precipitate any lead that may be still in solution, filter and wash with cold water. Lead a stream of hydrogen sulphide into the filtrate to precipitate arsenic, cadmium, bismuth, and copper. Filter and wash precipitate on filter with water containing hydrogen sulphide. The filtrate now contains only zinc and iron and can be thrown away. Remove the filter paper with the filtrate to a small dish and digest the whole with freshly prepared yellow ammonium sulphide. Cadmium, copper, and bismuth, being insoluble in yellow ammonium sulphide, are filtered off. The filtrate contains now only arsenic which may be determined volumetrically by Pearce's method, or it may be precipitated by hydrogen sulphide, filtered through a small glass tube containing asbestos. The tube and asbestos have been previously heated, cooled, and weighed. When the whole of the precipitate has been transferred to the little tube, it is warmed to drive off the greater part of water, and then gently heated while a stream of carbon dioxide passes through it. Allow the tube to cool while the gas still passes through, finally cut off the gas supply, place the tube in a desiccator for a few minutes, and then weigh. The increase in weight represents arsenic sulphide As_2S_3, which contains 60.98% arsenic. The filter and residue insoluble in yellow ammonium sulphide are heated in the dish nearly to boiling

with dilute nitric acid (1 part of acid to 2 parts of water). When the precipitate is dissolved, filter, wash the paper slightly, dry, incinerate it, and add the ashes to the nitric acid solution. Nearly neutralize the filtrate with pure caustic potash, add sodium carbonate and a little c. p. potassium cyanide and heat gently. If a precipitate is formed, it is filtered off, washed, and dissolved in nitric acid, and the bismuth precipitated by ammonium carbonate and weighed as bismuth oxide. To the filtrate a little more potassium cyanide is added, together with a few drops of yellow ammonium sulphide, which precipitates the cadmium. The precipitate is filtered off, tried, and weighed as cadmium oxide, with the necessary precautions to avoid the evaporation of the cadmium. (*b*) No, cadmium cannot be determined volumetrically by means of ferrocyanide in this case. (*c*) Pearce's method can be used after separation of the other metals, as described above.

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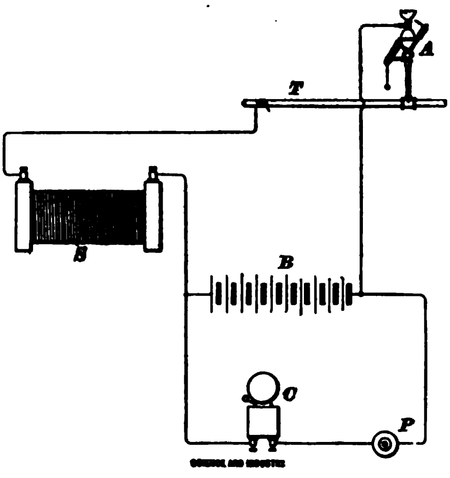
(145) (*a*) How should a gas fixture, which has on it wires for gas lighting, be taken down? (*b*) How should a gas fixture be connected up for gas lighting? (*c*) Will it make any difference if the connections between the fixture wires and the ceiling wires become interchanged when replacing a fixture? (*d*) Show by a sketch how a battery may be connected up so that it may be used for both a push button and bell circuit and for a gas-lighting circuit.

T. J., Germantown, Pa.

ANS.—(*a*) Pull down the wires from the ceiling a little ways, then either disconnect



or cut the fixture wires from the ceiling wires at or near the point at which they were connected. Unscrew and take down the fixture. (*b*) The wires leading to the burner may be run either inside of the brass tubes surrounding the gas pipes, or the wires may be fastened onto the outside of the brass tubes or pipes. The wires may be held in place on the top of the brass tubes by a little shellac. A thread may be wound around tube and wire, which will hold the wire in place till the shellac sets; then remove the thread. (*c*) If an automatic burner is used, the two fixture wires must be connected to the two ceiling wires in the same manner as before. If the wires become interchanged, the gas will light when the dark button is pushed and be put out when the light button is pushed, which is directly the reverse of the usual action. If the fixture is connected up incorrectly, you can reverse the connection of the two wires at the double push button, which will cause the burner to act properly. (*d*) See accompanying sketch. *A* is a pendant burner. *T* a gas pipe, to which one wire from spark coil *S* is connected. *B* is a battery. *C* is a bell which is connected to the push button *P*.

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(146) (*a*) Kindly inform me if there is any chemical that can be mixed with Portland cement in making joints for vitrified sewer pipe, to prevent the roots of trees and shrubs growing into the joints? (*b*) Please inform me what a fish trap is, relative to a water system.

C. G. B., Hot Springs, Wyo.

ANS.—(*a*) We do not know of any chemical that will prevent the trouble you state. If the pipe layer lays the pipes properly there will be no occasion for chemicals, because tree roots will not enter a sewer pipe except through cracks or other openings in the pipes or their joints. Of course it is necessary to lay the pipes on an unyielding bed so that they will not settle. We believe a good joint can be made as follows: Calk one strand of oakum into the joint, put clay over the opening, leaving a "gate" on top, then run the joint full of hot melted pitch and tar mixed in the proper proportion required to form an elastic joint when cold. This, however, will cost more than the ordinary cement joint. (*b*) A fish trap is a screen inside a water pipe or specially prepared chamber, that will prevent the passage of fish with the water. It will not prevent mud from passing through, but will intercept large solids in the water. To prevent the fish trap from being broken by the pressure it is customary to make the screen of solid bars, and the casing should be provided with a hand hole for access to the screen.

***

(147) What would be the best and most economical way of heating a tank of water $50' \times 30' \times 6\frac{1}{2}'$ to a temperature of 60°. The temperature of the room is 70° and the tank rests on the floor.

J. W. W., Fargo, N. Dak.

ANS.—Your method of heating the water

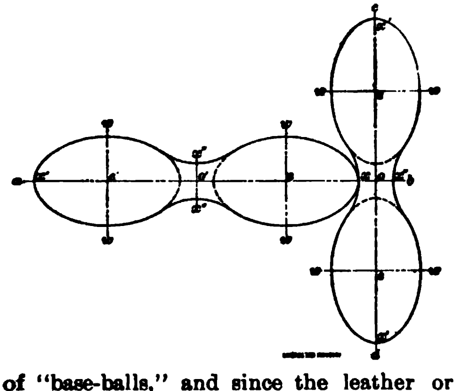
would be governed somewhat by the means at your disposal, the construction of the pool, and the conditions surrounding the case. If you can take a branch from the exhaust pipe of an engine, or exhaust muffle tank, and run a pipe coil in the bottom of the tank, you may be able to heat the water without any cost, further than the installation of the heating coil and perhaps a thermostat also. If, however, you cannot receive heat from a heating or power plant now in the building, we believe the most economical plan to adopt for heating the water is by the use of a regular hot water heater such as is commonly employed to warm buildings. The heater should be located outside of the tank and at a point lower than the bottom of the tank. Two circulating pipes should connect it to the tank, and the water in the tank will circulate through the heater. The size of heater required to do the work can be determined by the manufacturer after you tell him how much water is required to be heated per hour. To ensure a uniform temperature in the tank, it is necessary to connect both of the circulating pipes at the bottom of the tank, and they should be quite large. A thermostat may be used to regulate the dampers of the heater.

***

(148) Explain the method of developing a pattern for the cover of a sphere.

H. W. B., Hamilton, Pa.

ANS.—It is not possible to obtain an exact flat, or plane, pattern for the covering of a sphere. Approximate patterns in gores, zones, or in the form here shown must invariably be submitted to a stretching, or raising, process before they will conform to the shape of the solid in question. The two-pieced pattern here described is familiar to all on account of its use for the covering



of "base-balls," and since the leather or skin is always applied to the sphere and sewed on while damp the needed stretching is done without additional labor. The construction given is not a desirable one to use in the case of a metal covering for the sphere. Draw ab and cd at right angles to each other and in the relative positions shown by the accompanying sketch. Indicate the point of intersection by the letter o and set off the spaces oe on ab and cd equal to one-quarter the circumference of the sphere. Also set off eo' and $o'e'$ on ab equal to oe. Draw perpendiculars through points e and e' and make each space ew equal to one-eighth the circumference of the sphere. The width of the pattern through its narrow portion may be determined at pleasure, and the distance ox accordingly set off on ab equal to one-half of this width. Next, set the dividers to the distance ex, and from the points e and e' on ab and cd mark the positions of points x' at the extremities of the pattern. Set the dividers to the distance ox and set ox'' and $o'x''$ as shown. The outline of the pattern may now be conveniently determined by drawing the four ellipses shown in the illustration and by completing the pattern with freehand curves that shall pass through the points x''.

***

(149) (*a*) How can an ellipse be turned on a common wood lathe? (*b*) Will you recommend a good book on wood turning?

H. L., Joplin, Mo.

ANS.—(*a*) We know of no method of turning an ellipse on a common wood lathe without fitting up some special device. Where wood lathes are fitted for turning ellipses an iron ellipse, similar to the one to be turned, is placed on a spindle back of the lathe and a point on the tool carriage brought in contact with it. The tool carriage is usually held against the ellipse by a heavy weight or spring, the carriage being free to slide on the cross-rails as the ellipse revolves, hence as this ellipse revolves it will feed the tool in and out. Then by the use of the proper forming tools it is possible to turn an ellipse on a piece of wood fastened to the face plate of the lathe. The lathe must be arranged so that both spindles revolve together. A similar device is used for turning shoe lasts, axe handles, etc., and the style of lathe most commonly used for this is frequently known by the name of Blanchard lathe, as a form having these special properties was developed by a man by the name of Blanchard. (*b*) For an elementary book on wood turning we may recommend "A Laboratory Course in Wood Turning," by M. J. Golden. Published by Harper Bros.

***

(150) (*a*) What is the standard price for 1 sq. ft. of heating surface per season for Boston? (*b*) How long should a pipe ½″, ¾″, 1″, 1¼″, 2″, 2½″, 3″, 3½″, 4″ in diameter be to make 1 sq. ft. of outside heating surface?

W. R., Brockton, Mass.

ANS.—(*a*) We do not know if there is a standard price for steam-heated surfaces in

Boston. Some people can furnish steam heat cheaper than others, because they have a surplus of exhaust steam that would otherwise go to waste. We think the price will depend largely upon the source of the steam, the kind of fuel used, the amount of surface to be heated and its distance from the boiler, etc. Under ordinary circumstances a square foot of radiation is equivalent to an average fuel consumption of about .02 lb. per hour, which is equal to about ½ lb. of coal per day, or about 100 lb. for the heating season. If coal costs $5.00 per ton, the net cost of the heat, not including labor, expenses, or defective combustion, etc., is 25 cents per sq. ft. per season. Some people are glad to get a chance to supply heat at a 20-cent rate, while it would not pay others to supply it at a 40-cent rate.

(*b*)

Feet.			
4.547	of ½	in. pipe	equals 1 sq. ft. of heating surface.
3.637	" ¾	" "	" " " " " " "
2.904	" 1	" "	" " " " " " "
2.301	" 1¼	" "	" " " " " " "
2.01	" 1½	" "	" " " " " " "
1.608	" 2	" "	" " " " " " "
1.328	" 2½	" "	" " " " " " "
1.091	" 3	" "	" " " " " " "
.955	" 3½	" "	" " " " " " "
.849	" 4	" "	" " " " " " "

***

(151) (*a*) How are lead traps made and who makes the machinery for the same? (*b*) What is the mixture of ammonia fittings? (*c*) Will natural gas absorb water? If so, how much; for example suppose a pipe horizontal to be half full of water and gas passing over. (*d*) How and what makes the coldest point of a house sweat when natural gas is used for heating? (*e*) How many heat units are there in a cubic foot of natural gas? (*f*) What is the best mixture for grinding in ground key work such as a stop and waste? J. H., Jamestown, N. Y.

ANS.—(*a*) Lead traps of the round pipe form are made by a patented process. The machines used for making these traps are built to order. Such a machine is built similar to the ordinary lead-pipe machine, excepting that it is provided with two pistons. Straight pipe is made while both pistons are moving. A bend is made by stopping one of the pistons. Any foundry and machine shop can make a lead-pipe or trap machine. (*b*) Ammonia fittings are generally made of cast iron, composed chiefly of No. 3 gray iron with a little of No. 1 mixed in. (*c*) Natural gas will absorb water until it becomes saturated, then it can absorb no more until the temperature be increased, when it will absorb more. The quantity of moisture it will absorb depends upon its degree of dryness, its pressure, and its temperature. Gas becomes saturated in a pipe containing water. (*d*) The watery vapor, being one of the products of combustion, condenses on the cold walls and produces what we call sweat. If the weather is very cold it covers the glass with ice. (*e*) About 1,000 British Thermal Units. (*f*) Ground emery and ground bath brick are often used for this work.

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(152) Will you be kind enough to answer the following questions. (*a*) How can I detect whether sewer gas is escaping from the wash bowl in my office? At times there is a gurgling noise, like air forcing its way through the traps, and at times a perceptible odor. The room is about 75 feet above the sewer in the street. (*b*) There is a nearly continuous rumbling noise in the hot water tank in the kitchen, and the flow from the taps up and down stairs is intermittent, flowing freely for about 15 seconds, and stopping almost entirely for the same length of time. Last year the taps worked all right. This irregular flow was only noticed this winter. The tank and fittings are of the usual kind. Can you suggest a remedy?

W. L. L., Ottawa.

ANS. (*a*) Is it probable that sewer gas enters your office when you hear the trap gurgle. To be sure of it, however, you should gum the edges of a piece of tissue paper then remove the basin plug and paste this paper over the waste hole. Paste a similar piece over the overflow holes of the basin, then watch them. If the pieces of paper become swollen out in the middle or are blown off the porcelain at any point it proves that the gurgling is due to sewer gas being blown into your office. If, however, the tissue paper is made concave, then it follows that the air in your office is drawn through the trap and into the waste pipe. In any case, however, there is too much danger present and the trap should be back vented. (*b*) It is impossible for us to state the cause of the intermittent supply to the fixtures by the brief description you present. The case appears to be one that requires a thorough investigation on the grounds. The rumbling of the boiler is presumably caused by the intermittent supply. It is possible that the service pipe is small, perhaps corroded inside also; and that an automatic cellar drainer, or a large pump have been connected recently to the service pipe and regularly affect your supply. We would advise an investigation of the premises by a skilled plumber. It is evident that the plumbing is old; at least it is not installed in accordance with modern sanitary ideas and we therefore advise that the plumber be instructed to smoke test the system.

Supplement to Science and Industry, May, 1902

STANDARD KEY WAYS

$\frac{1}{8}$" TAPER PER FOOT

Diameter Shaft. In.	Width. In.	Depth. In.	Diameter Shaft. In.	Width. In.	Depth. In.	Diameter Shaft. In.	Width. In.	Depth. In.	Diameter Shaft. In.	Width. In.	Depth. In.
1	$\frac{1}{4}$	$\frac{3}{32}$	5	$1\frac{1}{8}$	$\frac{3}{8}$	9	$1\frac{3}{4}$	$\frac{9}{16}$	13	$2\frac{1}{2}$	$\frac{3}{4}$
$1\frac{1}{8}$	$\frac{5}{16}$	$\frac{3}{32}$	$5\frac{1}{8}$	$1\frac{1}{8}$	$\frac{3}{8}$	$9\frac{1}{8}$	$1\frac{3}{4}$	$\frac{9}{16}$	$13\frac{1}{8}$	$2\frac{1}{2}$	$\frac{3}{4}$
$1\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{32}$	$5\frac{1}{4}$	$1\frac{1}{8}$	$\frac{3}{8}$	$9\frac{1}{4}$	$1\frac{3}{4}$	$\frac{9}{16}$	$13\frac{1}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$
$1\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$5\frac{3}{8}$	$1\frac{1}{4}$	$\frac{7}{16}$	$9\frac{3}{8}$	2	$\frac{5}{8}$	$13\frac{3}{8}$	$2\frac{3}{4}$	$\frac{7}{8}$
$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{8}$	$5\frac{1}{2}$	$1\frac{1}{4}$	$\frac{7}{16}$	$9\frac{1}{2}$	2	$\frac{5}{8}$	$13\frac{1}{2}$	$2\frac{3}{4}$	$\frac{7}{8}$
$1\frac{5}{8}$	$\frac{7}{16}$	$\frac{1}{8}$	$5\frac{5}{8}$	$1\frac{1}{4}$	$\frac{7}{16}$	$9\frac{5}{8}$	2	$\frac{5}{8}$	$13\frac{5}{8}$	$2\frac{3}{4}$	$\frac{7}{8}$
$1\frac{3}{4}$	$\frac{7}{16}$	$\frac{1}{8}$	$5\frac{3}{4}$	$1\frac{1}{4}$	$\frac{7}{16}$	$9\frac{3}{4}$	2	$\frac{5}{8}$	$13\frac{3}{4}$	$2\frac{3}{4}$	$\frac{7}{8}$
$1\frac{7}{8}$	$\frac{1}{2}$	$\frac{3}{16}$	$5\frac{7}{8}$	$1\frac{1}{4}$	$\frac{7}{16}$	$9\frac{7}{8}$	2	$\frac{5}{8}$	$13\frac{7}{8}$	$2\frac{3}{4}$	$\frac{7}{8}$
2	$\frac{1}{2}$	$\frac{3}{16}$	6	$1\frac{1}{4}$	$\frac{7}{16}$	10	2	$\frac{5}{8}$	14	$2\frac{3}{4}$	$\frac{7}{8}$
$2\frac{1}{8}$	$\frac{1}{2}$	$\frac{3}{16}$	$6\frac{1}{8}$	$1\frac{1}{4}$	$\frac{7}{16}$	$10\frac{1}{8}$	2	$\frac{5}{8}$	$14\frac{1}{8}$	$2\frac{3}{4}$	$\frac{7}{8}$
$2\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{16}$	$6\frac{1}{4}$	$1\frac{1}{4}$	$\frac{7}{16}$	$10\frac{1}{4}$	2	$\frac{5}{8}$	$14\frac{1}{4}$	$2\frac{3}{4}$	$\frac{7}{8}$
$2\frac{3}{8}$	$\frac{5}{8}$	$\frac{1}{4}$	$6\frac{3}{8}$	$1\frac{1}{2}$	$\frac{1}{2}$	$10\frac{3}{8}$	$2\frac{1}{8}$	$\frac{5}{8}$	$14\frac{3}{8}$	3	$\frac{7}{8}$
$2\frac{1}{2}$	$\frac{5}{8}$	$\frac{1}{4}$	$6\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{2}$	$10\frac{1}{2}$	$2\frac{1}{8}$	$\frac{5}{8}$	$14\frac{1}{2}$	3	$\frac{7}{8}$
$2\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{4}$	$6\frac{5}{8}$	$1\frac{1}{2}$	$\frac{1}{2}$	$10\frac{5}{8}$	$2\frac{1}{8}$	$\frac{5}{8}$	$14\frac{5}{8}$	3	$\frac{7}{8}$
$2\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{4}$	$6\frac{3}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$	$10\frac{3}{4}$	$2\frac{1}{8}$	$\frac{5}{8}$	$14\frac{3}{4}$	3	$\frac{7}{8}$
$2\frac{7}{8}$	$\frac{3}{4}$	$\frac{1}{4}$	$6\frac{7}{8}$	$1\frac{1}{2}$	$\frac{1}{2}$	$10\frac{7}{8}$	$2\frac{1}{8}$	$\frac{5}{8}$	$14\frac{7}{8}$	3	$\frac{7}{8}$
3	$\frac{3}{4}$	$\frac{1}{4}$	7	$1\frac{1}{2}$	$\frac{1}{2}$	11	$2\frac{1}{8}$	$\frac{5}{8}$	15	3	$\frac{7}{8}$
$3\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{4}$	$7\frac{1}{8}$	$1\frac{1}{2}$	$\frac{1}{2}$	$11\frac{1}{8}$	$2\frac{1}{8}$	$\frac{5}{8}$	$15\frac{1}{8}$	3	$\frac{7}{8}$
$3\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{4}$	$7\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$	$11\frac{1}{4}$	$2\frac{1}{8}$	$\frac{5}{8}$	$15\frac{1}{4}$	3	$\frac{7}{8}$
$3\frac{3}{8}$	$\frac{7}{8}$	$\frac{5}{16}$	$7\frac{3}{8}$	$1\frac{5}{8}$	$\frac{1}{2}$	$11\frac{3}{8}$	$2\frac{1}{4}$	$\frac{3}{4}$	$15\frac{3}{8}$	$3\frac{1}{4}$	1
$3\frac{1}{2}$	$\frac{7}{8}$	$\frac{5}{16}$	$7\frac{1}{2}$	$1\frac{5}{8}$	$\frac{1}{2}$	$11\frac{1}{2}$	$2\frac{1}{4}$	$\frac{3}{4}$	$15\frac{1}{2}$	$3\frac{1}{4}$	1
$3\frac{5}{8}$	$\frac{7}{8}$	$\frac{5}{16}$	$7\frac{5}{8}$	$1\frac{5}{8}$	$\frac{1}{2}$	$11\frac{5}{8}$	$2\frac{1}{4}$	$\frac{3}{4}$	$15\frac{5}{8}$	$3\frac{1}{4}$	1
$3\frac{3}{4}$	$\frac{7}{8}$	$\frac{5}{16}$	$7\frac{3}{4}$	$1\frac{5}{8}$	$\frac{1}{2}$	$11\frac{3}{4}$	$2\frac{1}{4}$	$\frac{3}{4}$	$15\frac{3}{4}$	$3\frac{1}{4}$	1
$3\frac{7}{8}$	1	$\frac{5}{16}$	$7\frac{7}{8}$	$1\frac{5}{8}$	$\frac{1}{2}$	$11\frac{7}{8}$	$2\frac{1}{4}$	$\frac{3}{4}$	$15\frac{7}{8}$	$3\frac{1}{4}$	1
4	1	$\frac{5}{16}$	8	$1\frac{5}{8}$	$\frac{1}{2}$	12	$2\frac{1}{4}$	$\frac{3}{4}$	16	$3\frac{1}{4}$	1
$4\frac{1}{8}$	1	$\frac{5}{16}$	$8\frac{1}{8}$	$1\frac{5}{8}$	$\frac{1}{2}$	$12\frac{1}{8}$	$2\frac{1}{4}$	$\frac{3}{4}$	$16\frac{1}{8}$	$3\frac{1}{4}$	1
$4\frac{1}{4}$	1	$\frac{5}{16}$	$8\frac{1}{4}$	$1\frac{5}{8}$	$\frac{1}{2}$	$12\frac{1}{4}$	$2\frac{1}{4}$	$\frac{3}{4}$	$16\frac{1}{4}$	$3\frac{1}{4}$	1
$4\frac{3}{8}$	1	$\frac{5}{16}$	$8\frac{3}{8}$	$1\frac{3}{4}$	$\frac{9}{16}$	$12\frac{3}{8}$	$2\frac{1}{2}$	$\frac{3}{4}$	$16\frac{3}{8}$	$3\frac{1}{2}$	1
$4\frac{1}{2}$	1	$\frac{5}{16}$	$8\frac{1}{2}$	$1\frac{3}{4}$	$\frac{9}{16}$	$12\frac{1}{2}$	$2\frac{1}{2}$	$\frac{3}{4}$	$16\frac{1}{2}$	$3\frac{1}{2}$	1
$4\frac{5}{8}$	$1\frac{1}{8}$	$\frac{3}{8}$	$8\frac{5}{8}$	$1\frac{3}{4}$	$\frac{9}{16}$	$12\frac{5}{8}$	$2\frac{1}{2}$	$\frac{3}{4}$	$16\frac{5}{8}$	$3\frac{1}{2}$	1
$4\frac{3}{4}$	$1\frac{1}{8}$	$\frac{3}{8}$	$8\frac{3}{4}$	$1\frac{3}{4}$	$\frac{9}{16}$	$12\frac{3}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	$16\frac{3}{4}$	$3\frac{1}{2}$	1
$4\frac{7}{8}$	$1\frac{1}{8}$	$\frac{3}{8}$	$8\frac{7}{8}$	$1\frac{3}{4}$	$\frac{9}{16}$	$12\frac{7}{8}$	$2\frac{1}{2}$	$\frac{3}{4}$	$16\frac{7}{8}$	$3\frac{1}{2}$	1

COMPLIMENTS OF

SCIENCE AND INDUSTRY

SCRANTON, PA.

SCIENCE AND INDUSTRY

Vol. VII June, 1902 No. 6

DUTY TEST OF A HIGH-SERVICE PUMPING ENGINE

W. H. WAKEMAN

AN EXPLANATION OF THE PROCESSES BY WHICH THE DUTY OF A PUMPING ENGINE IS DETERMINED

THE duty of a pumping plant is usually stated as the number of foot-pounds that it develops while 100 pounds of coal of a given quality are burned under the boilers. It may be stated as the number of foot-pounds developed while a given number of heat units are disposed of, or developed under the boilers.

If it is based on the consumption of 100 pounds of coal, containing 14,500 heat units per pound, then the duty is actually given as the number of foot-pounds developed while $100 \times 14,500 = 1,450,000$ heat units are evolved or disposed of. If the duty is based on the consumption of 1,450,000 heat units, and the coal used contains 13,000 heat units per pound, then the number of foot-pounds developed while $1,450,000 \div 13,000 = 111.5$ pounds of coal are burned, is the duty obtained. In the foregoing cases the result shows the efficiency of both boiler and engine, which is satisfactory where the entire plant is supplied by one firm, but in many cases the engine is built by one party, and the boiler by another, therefore the engine builder is required to guarantee a certain duty for his engine, without regard to the boiler. In such cases neither the efficiency of the boiler, nor the quality of coal used is taken into consideration, as it is unnecessary.

The engine builder guarantees his pumping engine to develop a certain number of foot-pounds, while 1,000 pounds of commercially dry steam are delivered to it.

This makes it necessary to carefully weigh the water pumped into the boiler. Steam delivered to the engine must be tested and the amount of water it contains subtracted from the total delivered to the boiler. The remainder is the amount of dry steam delivered. Or the percentage of dry steam may be determined, and the total weight of water pumped into the boilers multiplied by it, which gives the weight of dry steam without subtraction. When this method is used, the percentage is considered as a fraction, and not as a whole number. It is used in this case, as will appear later on.

In order to illustrate the process used for determining the efficiency of a common type of pumping engine, the actual results, secured from one of them are given, and the calculations explained. It is a vertical, triple-expansion, condensing engine with cylinders of the following diameter: High pressure, 30 inches, intermediate, 54 inches, low pressure, 80 inches. These are given merely as a

matter of interest, as they have no direct bearing on the case.

The piston in each of these cylinders drives a single-acting water piston 25.5 inches in diameter, with a stroke of 64 inches, all of which must be taken into consideration, in order to determine the foot-pounds of work developed.

The general formula that applies to an engine of this kind may be stated as follows:

$$\text{Foot-pounds} = \frac{R\,H\,W}{\pi \times 4 \times 12 \times 144}\left[(\pi\,d_1)^2 S_1 + (\pi\,d_2)^2 S_2 + (\pi\,d_3)^2 S_3\right].$$

In which $R =$ total number of revolutions. $H =$ head pumped against in feet. $W =$ weight of 1 cubic foot of water at given temperature.

$d_1\,d_2\,d_3 =$ diameter of high pressure, intermediate, and low-pressure water pistons, respectively.

$S_1\,S_2\,S_3 =$ strokes of the same pistons in inches.

As the Greek letter π signifies the circumference of a circle whose diameter is 1, it will at once be noted that much of the above formula refers to the diameter of the water pistons, and this may be very much simplified, as follows:

The area of a circle may be determined by the following formula $\frac{(\pi\,d)^2}{\pi 4} = A.$

In which d is the diameter and A the area in square inches, if d is stated in inches. Applying this to a circle 25.5 inches in diameter results as follows: $\frac{(3.1416 \times 25.5)^2}{3.1416 \times 4} = \frac{6,417.74027}{12.5664}$ $= 510.7$ square inches.

This shows that we may omit $\pi \times 4$ below the line, and $\pi\,d^2$ wherever it occurs between brackets, if we substitute A between the brackets, signifying the area in square inches, which may be obtained from a table of areas of circles.

The formula now appears in a much more simple form, as follows:

$$\text{Foot-pounds} = \frac{R\,H\,W}{12 \times 144}\left[(A\,S_1) + (A\,S_2) + (A\,S_3)\right].$$

The formula as first given, also as it now stands, can be applied to any single-acting triple-expansion engine, whether the water pistons are all of the same diameter or not, and to cases where the strokes vary, but in the case under consideration they are all alike, therefore the following applies:

$$\text{Foot-pounds} = \frac{R\,H\,W}{12 \times 144} \times (A \times S \times 3).$$

R denotes the total revolutions and S the stroke in inches, therefore, when these two factors are multiplied together as they really are when the formula is applied, the result is the piston travel in inches, and when we divide by 12 below the line, the quotient is the piston travel in feet, while the pump is delivering water. If the stroke is stated in feet, as represented by S, then we might eliminate 12, but this would not be convenient in some cases, of which our example is an illustration, for the stroke is 64 inches, making it impossible to use a decimal fraction, and if the common fraction $5\frac{1}{3}$ is used it is not so convenient as to use the stroke in inches and divide by 12.

144 is used in the divisor because there are 144 square inches in a square foot, therefore the area of the piston is reduced to square feet.

When the area of the piston in square feet is multiplied by the travel of the piston in feet, the result is cubic feet, and when this is multiplied by the weight of 1 cubic foot W the product is the weight of water raised. When the weight of water in pounds is multiplied by the head H in feet, the product is foot-pounds. If the height above the pump, in feet, is determined

by measurement, it does not include the friction of the flow of water, which is a legitimate part of the load; but when the pressure in the discharge pipe at the pump is indicated by a gauge, and the height in feet is determined by calculation, friction is included and the pump receives credit for its full load.

If the source of supply is located above the pump, it must be deducted from the discharge head, and if below, it must be added to it.

In this case the number of revolutions, as shown by a counter, is 23,671, and as the pumps are single acting, there is only one stroke to be considered for each revolution, instead of two as in the case of a double-acting pump.

The source of supply is above the pump, and after accounting for this the actual head, including friction, is 293.89 feet.

The temperature of the water is 79° F., the weight of which is 62.195 pounds per cubic foot.

We have already determined that a circle 25.5 inches in diameter contains 510.7 square inches.

Substituting figures that apply to this case for letters in the general formula results as follows:

$$\frac{23,671 \times 293.89 \times 62.195}{12 \times 144} \times (510.7 \times 64 \times 3) = \frac{432,670,102.46}{1,728} \times 98.054.4 = 24,551,624,515 \text{ foot-pounds.}$$

As the duty of this engine is to be stated in foot-pounds developed while 1,000 pounds of steam are passing through the cylinders, it becomes necessary to determine this, and the following formula is given for this purpose:

$$\text{Duty} = \frac{R\ H\ W}{1,728}\left[(AS_1) + (AS_2) + (AS_3)\right]\frac{1,000}{\text{Steam}}$$

The explanation given for the first formula applies to this, so far as the meaning of symbols is concerned, except that the word "steam" means the total weight of steam used.

In reality it is just the same as that given to determine the foot-pounds developed, except that one more factor is added. $R\ H\ W$ is to be divided by 1,728 but in the other one $12 \times 144 = 1,728$.

The first formula introduced in this article, or the last one mentioned, except the latter part of it which is $\frac{1,000}{\text{Steam}}$, may be used to determine the foot-pounds developed during the test.

The number of foot-pounds developed is to be divided by the pounds of dry steam used during the test. In this case 153,398 pounds of water were pumped into the boilers, and a calorimeter test showed that but very little water entered the engine, as .998 of the mixture was steam. Therefore, $153,298 \times .998 = 153,091$ pounds of dry steam were used. Then $24,551,624,515 \div 153,091 = 160,372$ foot-pounds developed for 1 pound of steam, and for 1,000 pounds it is $160,372 \times 1,000 = 160,372,000$ foot-pounds which is the duty of this engine under given conditions. The contract in this case called for a duty of 125,000,000 foot-pounds with a bonus of $1,000 for each million above the standard, and a forfeiture of $2,500 for each million below it. The result entitled the builders to a bonus of $35,372.

This pumping engine was built to deliver 10,000,000 gallons of water per 24 hours, at a reasonable speed, and during the test this was exceeded by 48,000 gallons.

MAKING JOINTS

THERE is scarcely any other one thing that impresses a visitor to a steam plant with the idea that the engineer is careless and slovenly as leaking pipe joints, pump flanges, and possibly the cylinder head and steam-chest cover. The engineer may be dirty and practically covered with oil and grease, and the floor may have the appearance of having been neglected for some time, or the engine may pound a little or leak a little steam at the stuffingbox, but somehow these things do not impress one with the idea that the man in charge is negligent and belongs to the don't-care class, as do leaky joints that ought to be steam-tight and of a more or less permanent character. The dirty engine is immediately excused upon the ground of long runs without stopping, and that the excess of oil is a necessity to prevent heating in some of the bearings, or at the crankpin, and the pounding is frequently excused for the same reasons, which reasons may be and oftentimes are purely imaginery, still, any one who has run engines, and especially high-speed engines, knows the difficulty of keeping an engine cool with a reasonable amount of oil, and too, that it is better to hear a box pound than to smell burning oil.

If the plant is a large one, and the number of men rather small for the amount of work to be done (which is far too often the case) one would scarcely expect to find a very clean floor, or clean engine for that matter.

The impression regarding joints, however, is that when a joint is properly made it should be steam-tight and be more or less permanent. That a well-made joint should last for many months is very true, but this result can only be realized when the material put into the joint is of good quality, and when the person making the joint understands this part of the engineer's work.

When about to make a joint, whether a flange or screw joint, the surfaces should be thoroughly cleaned so that no foreign substance may prevent the threads from coming in contact with each other all around the pipe in the screw joints, nor prevent the faces of the flanges from pressing evenly against the packing, whatever kind it may be. Another important point in making a joint is to see that the two lengths of pipe are in line with each other. A great many times the cause of leaky joints is attributed to the packing, and it is said to be too soft or too hard, too thick or too thin, when really the cause of the trouble could be traced to a lack of true alinement.

When horizontal pipes are out of line vertically they can as a rule be straightened more readily than when out of line sidewise, especially when they are carried on brackets attached to a wall or suspended from the ceiling by any of the well-known pipe hangers. Long lengths of piping can generally be straightened more readily than short ones owing to the possibility of obtaining more "spring" or flexibility. When long lengths of piping have sagged, or have moved sidewise, rendering it difficult to bring the ends squarely together, they may be strengthened by blocking up or by shifting the position of the hangers, but with short lengths, which are more rigid, another method will usually be necessary in order to secure a tight

joint. An instance where blocking or springing generally fails to bring flanges squarely together is frequently found in making boiler connections, and it generally occurs with pipe of rather large diameter. Fig. 1 represents a case of this kind. Either the fittings have not been tapped straight or the pipe is slightly bent, with the result that the flanges are separated more on one side than on the other. It will be useless in nearly all cases to attempt to produce a tight and lasting joint by fitting a gasket of uniform thickness, and attempting to draw the flanges squarely together by means of the flange bolts. A wedge-shaped gasket, or what is commonly called a "dutchman," is needed here, and frequently is used in connection with the regular gasket. The application of a dutchman is illustrated in Fig. 2. It is nothing more or less than a wedge-shaped gasket. For high pressure it should be made of metal, either cast or wrought iron, and for light pressure, of wood. When the angle between the flanges is slight the dutchman may consist of a wedge-shaped rubber gasket, which may either be used with the regular gasket or alone, depending upon the thickness of the material at hand. When the dutchman is of metal it is generally necessary to put in a thin gasket of uniform thickness on either side unless the surfaces of the flanges and the dutchman have been properly prepared for a metal-to-metal joint, which, however, is seldom the case. When it is practicable to do so, the dutchman should be made a snug fit and put in while the pipe is cold. As with other joints of this kind, the flange bolts should be drawn up snugly, but not too tight, when the pipe is hot, so as to prevent the gasket being blown out when it is again being heated and subjected to pressure.

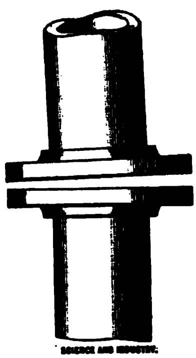


FIG. 1

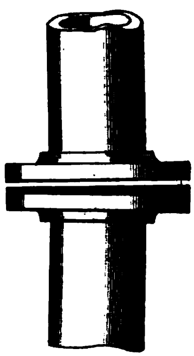


FIG. 2

A flange joint located about the middle of a long line of large pipe, where the faces of the flanges are parallel and close together, presents about as difficult a job of joint making as is often encountered. The most difficult part of the work is perhaps the removal of the old gasket after it has become baked on and is thoroughly hard. The pipe can be seldom moved endwise more than $\frac{1}{16}$, and often-times not more than $\frac{1}{32}$ of an inch, so that it is impossible to remove the gasket by chipping or filing. In this case an old hand saw will be found an excellent tool to use and in the manner illustrated in Fig. 3. The use of saws for this purpose is not new, although many persons have not thought of employing them. The saw is guided by the flanges and generally leaves a smooth, clean surface for the new gasket. When inserting a new gasket it will be easier, and better for the gasket, to insert it from the bottom. This may readily be done by tying a string to the gasket, see Fig. 4, then pulling it up between the flanges and inserting one of the upper bolts. The others can then be put in and the flanges drawn together. Gaskets have frequently been injured in places of this kind by attempting to push them sidewise or to poke them into place by means of a wire or a thin strip of iron or steel.

A number of the older styles of engines were built with separate steam chests, both the chest and the cover being secured in place by the long studs in the cylinder casting. With this

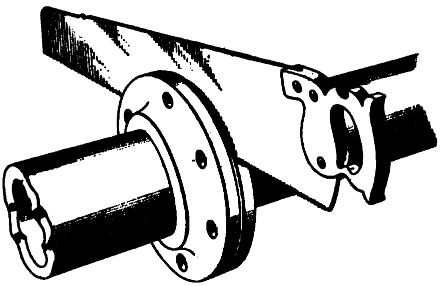


FIG. 3

arrangement when the steam chest cover is removed for the purpose of adjusting the valves or of repacking the joints between the cover and the chest, the joint between the chest and the cylinder is nearly always disturbed, which frequently necessitates the removal of the valves and the heavy chest casting in order to get at the joint next to the cylinder. Thin sheet lead will be found an excellent packing in places of this kind, or if the surfaces are wide enough, lead wire may be used and is somewhat cheaper. One of the surfaces should be coated with graphite, to prevent the gasket from sticking and tearing, where it is desired to break the joint. When using the wire place it both inside and outside the studs, as shown in Fig. 5, or partly around the studs, as in Fig. 6, and bevel or notch the ends, as shown in the same figures, so as to form a good joint. Soft copper wire is sometimes used, but in this particular construction the softer lead wire will be found preferable, owing to the lower tension required on the studs to press it into the proper form to make a tight joint. It will be noticed in Fig. 7 that the packing in this case cannot exceed a certain thickness without interfering with the proper working of the valve stem. When copper wire is employed it is generally laid in shallow grooves; the depth of which is such that when the surfaces are drawn tightly together they will not touch, as illustrated in Fig. 8, which also illustrates the grooves in the flange of a steam chest. Copper wire should be very soft when used for gaskets, and may be annealed, if found to be too hard, by heating it to a dull red color and plunging into cold water.

The materials used in making joints of all kinds are few in number, and most of them, when properly used, will be found to be reasonable in price and quite readily obtained. The commonest, and probably as reliable a material as any for making permanent joints, is red lead. It is practically indestructible, and can be readily compounded with white lead and boiled linseed oil, so as to form a joint of almost any thickness desired, according to the consistency of the putty thus

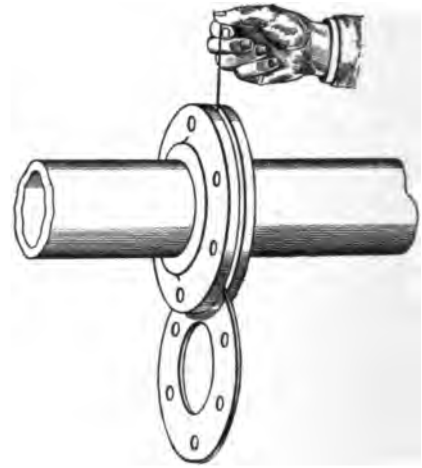


FIG. 4

made. Spread the putty on one of the surfaces forming the joint, with a putty knife or a pocket knife, if the former is not available. If the putty fails to adhere to the surface over which it is being spread, smear the latter with

tallow, which will usually increase adhesion. Then bring the two surfaces together, and the gradual tightening of the bolts will cause the lead or putty to ooze out at the edges till a point is reached when the friction between the particles of putty and the faces or surfaces of the joint equals or exceeds the pressure forcing the particles outward.

Such a joint, whether on a pipe or a steam chest, acquires an adhesiveness to the faces that requires a high pressure of steam, and therefore, considerable force to overcome. Red-lead joints are particularly well adaped to the stuffingbox end of a cylinder, viz., between the cylinder and the end of the frame forming the head, or the inside joint between a steam chest and a cylinder, and in fact for any joint that

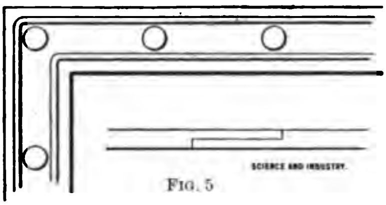


Fig. 5

is likely to be permanent. Cylinder oil of any kind rarely affects a well-made red-lead joint.

When the surfaces forming the joint are rough, as unplaned surfaces are likely to be, leaded candle wicking or asbestos wicking is oftentimes added, but this method is not thoroughly reliable where the joint is subjected to high pressures and temperatures, for when the candle wicking becomes thoroughly dry it soon forms a powder and the joint begins to leak at once. Asbestos wicking acts in much the same manner, but requires a longer time before becoming entirely useless. With faced surfaces and in certain places, as for instance, the cylinder head of an engine, by which the cylinder is bolted to the frame, the latter having a projection fitting into a recess in the cylinder flange, a joint much thicker than is desired may be the result. Where, however, the putty has no time to harden, and the bolts

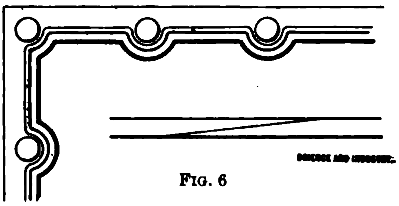


Fig. 6

or flanges are weak and the bolts widely spaced, a piece of asbestos wicking is preferable. When packing the flanges of copper pipe, a piece of asbestos wicking is oftentimes indispensable. With thin flanges, that part of the flange lying between the bolts may not press the joint as firmly as that portion near the bolts, and the wicking is thus gripped hard at the bolts, while that part of the wicking between the bolts helps to hold the putty while yet soft and keeps it from being blown out.

Joints for boiler mountings are often made with wire gauze and red-lead putty. The gauze makes the joints, but the putty is pressed into the gauze, and

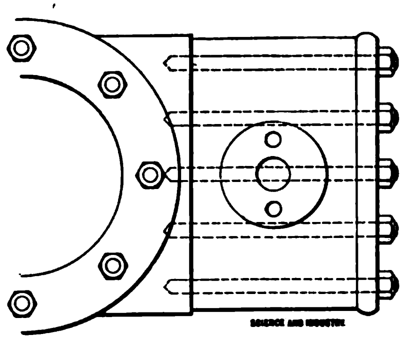


Fig. 7

the roughness of the latter enables the putty to resist a greater pressure than it otherwise would without oozing out. For some purposes, for instance, that of putting a patch on a boiler, red-lead

putty is not infrequently mixed with chopped fiber of spun yarn. This has a binding effect upon the putty which will be found very advantageous when the joint varies much in thickness. But red lead is disagreeable stuff to handle when soft, and gives trouble when attempting to clean it off after hardening, especially if studs project from the faces forming the joint.

For joints that are frequently taken apart some cleaner material is desirable. Lead wire, as previously stated, makes an excellent joint for cylinder heads and steam-chest covers. This material withstands the effects of cylinder oils, but where high pressures are carried, copper should be used, for this possesses all the good qualities of the lead, and has the additional advantage of providing a stronger as well as a thicker joint—where the latter may be found necessary.

Flat cotton lamp wicking dipped in boiled linseed oil, with the surplus oil removed, makes a good joint, and one that may be used two or three times, provided the wicking is given a coating of graphite each time the joint is taken apart. Sheet-rubber packing makes a clean joint and under certain conditions a very good and lasting one. Sheet rubber, however, when exposed to heat for a considerable length of time, becomes very adhesive, and may require chipping off when the joint is broken.

Rubber used in the form of rings is often thicker than is necessary unless the flanges are very rough. When the surfaces are not planed or otherwise made smooth, thick joints may have some advantage, as they will stand more compressing than thin ones; but when a joint is thick, the pressure on the inner edges of the packing is not balanced, and is apt to be greater where the joint is least tightly gripped. The tendency is to blow out the packing at that point, not altogether, but enough to allow steam to escape. As the rubber softens, such joints are tightened again by hand while they are hot.

A simple and quick method of cutting gaskets for pipe flanges, cylinder heads, steam-chest covers, etc. consists in laying the sheet of packing over the plate, flange, or head as the case may be, and taking a hammer and striking the packing over the edge of the plate, when the edge will be found to cut through the packing, as shown in Fig. 9. When cutting the bolt holes, use the peen of the hammer, permitting the peen to fall squarely over the hole. The result thus produced will be found to closely resemble a punch. After cutting one hole on opposite sides of the sheet, drop a bolt into the holes to prevent the packing from moving, which will insure the remainder of the holes coming in the proper place. Gaskets cut in this manner never fail to fit exactly when placed in position in the joint.

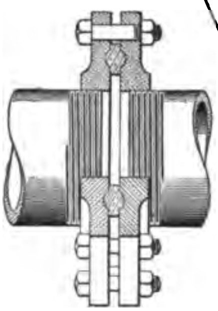
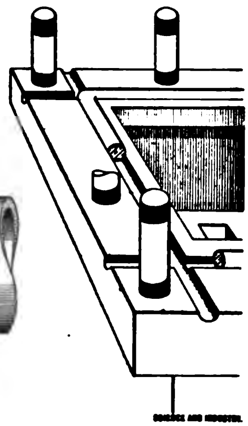


FIG. 8



When cutting rubber packing with a knife, dip the blade into water in which a little sal soda has been previously dissolved. This furnishes an excellent lubricant practically without cost.

Sheet asbestos softens quickly when

saturated with water or boiled linseed oil. This makes a useful material for uneven joints, as it yields under the tightening of the bolts so as to fill any depressions. For water pressure, especially when the joint is not subjected to much heat, canvas previously coated with red lead makes a lasting joint, but if the joint is to be frequently broken the canvas should be given a coating of graphite mixed with a little good cylinder oil. Drawing paper, and best of all, old flour sacks make a good joint for cylinder heads and steam chests for pressures not exceeding 125 pounds per square inch. Paper joints are always to be given a coating of graphite which should be repeated each time the joint is broken.

Paper joints when properly leaded (with graphite) may be used twice, and in some cases three times where the pressure of steam is quite low. Paper, especially the kind mentioned, makes a good and cheap joint for atmospheric pressure.

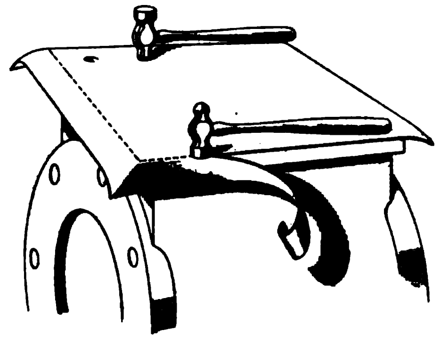


FIG. 9

When making a screwed joint for gas, especially the gas from naphtha and gasoline as it is used in gas furnaces, a coating of shellac will be found of advantage.

Round rubber, or, better still, rubber tubing, makes an excellent joint for handhole and manhole plates. Although this makes a thick joint it is safe for this purpose, as the raised portion of the plate which enters the hole prevents the gasket from blowing out and, too, as handhole and manhole plates are not made as true as it is possible to make them, a thick gasket of round rubber will be found preferable to the flat ones. These should be given a coating of graphite, which prevents sticking and breaking the gasket when taking out the plate.

Metallic gaskets for manhole and handhole plates in boilers, which have been principally of lead, are going or have gone out of use to a great extent, because where the surfaces of both the head and the plate are not unusually smooth and even, they have not given good satisfaction, all things considered. The best lead gaskets for this purpose require a specially designed plate as shown in Fig. 10, in which the flange is grooved in such a manner as to retain the soft metal so as to permit it being worked down, when occasion demands it, to an even surface and to prevent distortion when removing the plate. When a plate of this kind is put in and begins to leak when the pressure rises a few pounds, a sharp blow on the plate or boiler head from a moderately heavy hammer has generally been sufficient to stop the leak. A lead gasket of this kind should, of course, be returned to exactly the same place each time it is put in, in order to have the surface fit tightly enough to prevent leakage, which is a difficult operation with the ordinary construction of plates.

When putting up large steam pipe having flanges screwed on, a thoroughly tight joint may be had by putting in a copper gasket, preferably corrugated, $\frac{1}{32}$ of an inch thick (instead of rubber), between the flanges, provided the latter are true, and before the flanges are screwed on the pipe they may be slightly counterbored. After they

are screwed on, the counterbore is to be filled with lead, either by pouring melted lead into the recess and then caulking in hard against the threads, or by winding a piece of lead wire around the pipe having a diameter equal to the width of the counterbore, which is to be caulked into the recess. It often happens that the joint between the flanges will be perfectly steam-tight and that steam will issue from the joint between the pipe and the flange. This kind of a leak is a difficult one to stop in large pipes after they are all connected up, except by the use of the pipe clamp.

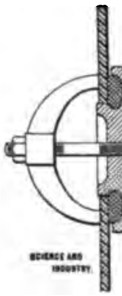


FIG. 10

When a screw joint in a large pipe begins to leak, it is frequently impossible to disconnect the entire line of piping in order to remake one joint. Such an operation in many cases would involve the expenditure of several hundred dollars. What are known as pipe clamps are readily obtainable and have been designed to meet the requirements of just such cases. These clamps consist of a main or outer ring made in halves and secured to the pipe near the joint, as shown in Fig. 11. Within this ring is a second one which is pushed outward and against the joint by a second set of screws. The packing is placed against the inner ring and is crowded into the joint by the outward movement of the inner ring. As will be seen, this device is easily applied, and, when the proper packing is employed, effectually stops the leak. As the packing gradually becomes dried and less pliable, the tendency is to shrink and to cause a leak to break out afresh. This is prevented by occasionally testing the screws, and seeing that the packing is at all times crowded firmly against the joint. An advantage offered by this means of stopping leaks is that the plant need not be closed down in order to apply it at the outstart nor when the packing requires renewal.

All joints except very thin putty joints, when made as described in the preceding lines, should be well tightened when the pipe is put up and when

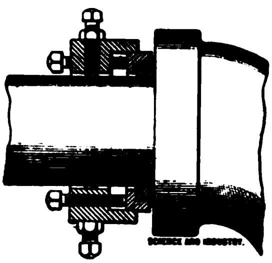


FIG. 11

the joint is first made, and after the joint has become thoroughly hot the bolts should be again tightened slightly. This is particularly the case when soft packing is used, such as sheet rubber and asbestos.

USEFUL FORMULAS—V

JOSEPH E. LEWIS, S. B.

HORSEPOWER TRANSMITTED BY BELTING, $\text{H. P.} = \frac{TWS}{33{,}000} = \frac{WS}{C}$

BELTS are usually made of leather tanned by oak bark. The best part of the hide is cut into strips, which are united into lengths by cementing, lacing, or riveting. Special kinds of leather are used where great strength is required. Pure vulcanized india rubber, or more often india rubber with interposed plies of strong canvas, is often used, especially in wet places where leather is unsuitable. Gutta-percha has been used, but it stretches permanently too much. Waterproof cotton woven belting is now used a good deal, and can be made of great width (up to 60 inches). It may be used in the open air and where exposed to dampness. Llama-hair belts have also been used to a limited extent.

Now, we may figure the horsepower of a belt in very much the same way that we figure that of an engine. We will start with the same fundamental conception; that is, the exertion of force through space. The force will be the tension in the belt, and the space will be the distance traveled by a point on the belt as it moves around the pulleys. It will be seen at once that the power of a belt increases with the speed at which it runs, so that a slowly moving belt will have to be much larger to transmit a given horsepower than a rapidly moving belt. Light belts running at high speeds are to be preferred to heavy belts running at slow speeds.

We will limit ourselves to the discussion of leather belts. They are either single or double, laced or cemented, and their power varies accordingly. The double belt will transmit more power than the single, and the cemented, or continuous belt, more than the laced.

The general formula commonly used in computing the horsepower of belting, is as follows:

$$\text{H. P.} = \frac{TWS}{33{,}000} = \frac{WS}{C}$$

in which

T = working tension of belt in pounds per inch of width;
W = width of belt in inches;
S = speed of belt in feet per minute;
C = speed of belt in feet per minute for 1 horsepower per inch of width.

Let us examine the first part, $\frac{TWS}{33{,}000}$.

The tension per inch of width should be for general service under usual conditions, $T = 60$ for double belts.

$T = 42$ for single belts.

For special service under very trying conditions, smaller values should be used, as follows:

$T = 47$ for double belts.

$T = 33$ for single belts.

We will now find the speed at which a single belt 1 inch wide must travel to transmit 1 horsepower. This value is called C. We have $T = 42$, $W = 1$, and H. P. = 1 to find S. From the formula $\text{H. P.} = \frac{TWS}{33{,}000}$ we obtain $1 = \frac{42 \times 1 \times S}{33{,}000}$, which, transposed and simplified, gives $S = \frac{33{,}000}{42} = 786$. This is the speed per horsepower per inch width. For single-laced belts, then, C is approximately 800.

Performing the same computation for double-laced belts, we have $60\,S = 33{,}000$, or $S = 550$ approximately for 1 horsepower per inch of width.

Then C for double-laced belts equals 550.

For cemented or continuous belts, values of T may be increased about 20%, giving smaller values for C and corresponding larger values for the amount of power that a given belt will transmit.

Now take the second part of the formula which is the one we use most in practice;

$$\text{H. P.} = \frac{WS}{C};$$

that is to say, the horsepower which a belt is capable of transmitting may be found by multiplying the width in inches by the speed in feet per minute, and dividing the product by the value of C for a given kind of belt. We may summarize the values of C as follows:

$$\text{Laced belts}\begin{cases}\text{single,} & C = 800.\\ \text{double,} & C = 550.\end{cases}$$

$$\text{Cemented belts}\begin{cases}\text{single,} & C = 640.\\ \text{double,} & C = 440.\end{cases}$$

The explanation of this formula is quite simple. If S is the speed of the belt and C is the speed for 1 horsepower for 1 inch of width, then S divided by C equals the number of horsepower per inch, and this, multiplied by the width of the belt, W, equals the total horsepower that it will transmit.

A simple rule to remember is that a single-laced belt 1 inch wide will transmit 1 horsepower when traveling at a speed of 800 feet per minute. The corresponding value for double belts is 550 feet per minute. For cemented belts somewhat smaller values may be used. The speed of a belt may be readily computed from the speed of the pulley rim over which it passes. If the pulley is 3 feet in diameter and is making 150 revolutions per minute, it is carrying the belt at a speed of about 1,400 feet per minute ($3.1416 \times 3 \times 150 = 1413.7$). A single-laced belt 1 inch wide on this pulley can transmit $1\frac{3}{4}$ horsepower, and a double belt of the same width, about $2\frac{1}{2}$ horsepower.

The rules given above are based upon 180° arc of contact and apply to horizontal belts. In the case of vertical belts, unless there is some means provided for keeping them tight, a liberal allowance should be made on these figures.

Where the arc of contact is less than 180°, a "rough and ready" correction is to increase the width of the belt proportionately for a given power; that is to say, let the belt width be proportional to the arc of contact in the inverse ratio. If a 10-inch belt should be used for a 180° arc in a given case, then for a 150° arc the width would be

$$\frac{180 \times 10}{150} = 12''.$$

Where the arc of contact is greater than 180° it is on the side of safety to figure the width the same as for 180°. These methods are not, of course, strictly accurate, but the writer believes that they represent conservative practice, and the error is always on the safe side.

If, however, it is desired to figure more accurately, the following table of coefficients, proposed by Mr. E. C. De Wolfe, may be used:

Arc of Contact	*Coefficient*
100	1.45
110	1.37
120	1.30
130	1.24
140	1.18
150	1.13
160	1.08
170	1.04
180	1.00
190	0.96
200	0.93
210	0.90
220	0.87
230	0.84
240	0.81
250	0.78

It will be noticed that a decrease of the arc to 150° requires a 13% increase

of belt width over the 180° requirement for the same horsepower, so that a 10-inch belt for 180° would be 11.3 inches wide for 150° instead of 12 inches, but it is obvious that a 12-inch belt ought to be used.

The power of a belt is also modified by centrifugal force, so that its efficiency at high speeds is less than at moderate speeds. Roughly speaking, if you run a belt twice as fast it will transmit twice as much power, but this statement is not strictly true and is more and more in error as the speed increases. The faster the belt moves, the greater the centrifugal force acting upon it and tending to reduce its adhesion to the pulley and thus to lessen its transmissive efficiency. It is, therefore, necessary to further modify the results which we have obtained above. It is obvious that a laced belt, due to the inferiority of the joint, will be affected to a greater extent by the action of centrifugal force than an endless, or cemented, belt. For this reason Mr. De Wolfe proposes two sets of coefficients, as follows:

Belt Speed Feet per Minute	*Coefficients Laced*	*Endless*
2,000	1.08	1.01
2,500	1.06	1.03
3,000	1.10	1.06
3,500	1.15	1.09
4,000	1.21	1.13
4,500	1.29	1.18
5,000	1.40	1.24
5,500	1.54	1.31
6,000	1.75	1.40

The width of belt computed by the methods already given should be multiplied by the coefficient corresponding to the speed and kind of belt.

There is a limit to the speed at which a belt may be run, beyond which any increase in speed results in an actual loss in the power transmitted, due to the action of centrifugal force as above described. This maximum speed varies for different kinds of belts. For laced belts the maximum power is at a speed of about 5,400 feet per minute, and for cemented belts at about 6,300 feet per minute. A rule easily remembered is that belt speed should never very much exceed one mile per minute.

To summarize: We have the formula H. P. $= \frac{WS}{C}$. $C = 800$ for single-laced belts, and 550 for double, and may be about 20% less in both cases for cemented belts. The results found by using this formula must be modified by the use of the first table for arcs of contact other than 180°, and by the second table for centrifugal force, particularly at high speeds.

Take a simple example: How wide must a double-laced belt be to transmit 150 horsepower at a speed of 4,500 feet per minute, for 150° contact.

$$\text{H. P.} = \frac{WS}{C},$$

$$W = \frac{\text{H. P.} \times C}{S} = \frac{1\cancel{5}\cancel{0} \times 55\cancel{0}}{\underset{3}{\cancel{4},\cancel{5}\cancel{0}\cancel{0}}} = 18\tfrac{1}{3}$$

$18\frac{1}{3} \times 1.13 \times 1.29 = 26.3''$. A 24-inch or 26-inch belt should be used, for a driven pulley say 30 inches in diameter. For smaller pulleys even a wider belt should be used. Roughly speaking, for a pulley 20 inches in diameter the belt should be 12% wider, and for one 12 inches in diameter about 25% wider.

A conservative rule which may be easily remembered, and which, it will be safe to use without correction in all ordinary cases, is that a single-laced belt 1 inch wide traveling at a speed of 1,000 feet per minute, will transmit 1 horsepower, and that a double-laced belt 1 inch wide traveling at a speed of 700 feet per minute will transmit 1 horsepower. Of course there is a difference in the quality of different belts, and consequently a difference in their transmissive power which cannot be taken account of by any general rule or formula. What we have said in this article applies to first-class belting.

MAGNET SYSTEM OF CONTROL FOR ELECTRIC ELEVATORS

R. B. WILLIAMSON

WITH the increasing number of isolated electric lighting plants and also with the extension of electric power transmission there has been a corresponding increase in the use of electric elevators. The electric elevator machine, in itself, does not usually trouble the engineer in charge to any great extent, but the same cannot be said of some of the controlling devices that have been installed in connection with them. Many of the controllers placed on the market in the past were so complicated, or flimsy in construction, that they were continually getting out of order, and in some quarters created a prejudice against electric elevators. As a result, efforts have been made to improve and simplify the construction of these controlling devices. Direct-connected electric elevators are now provided with controllers that perform the functions of starting, stopping, and reversing the motor, and which give little if any more trouble than the devices used in connection with an ordinary hydraulic elevator. It is our purpose to describe here one of these later types of controllers as used on elevators designed to run at a fairly high speed.

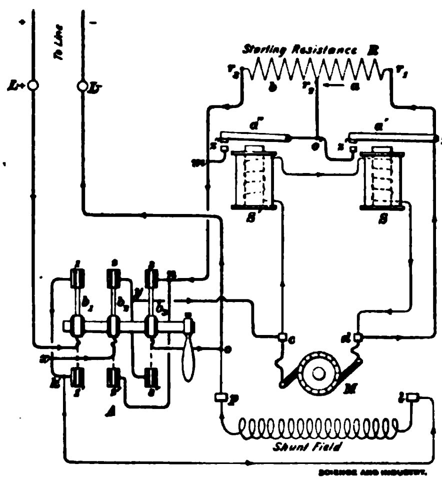


FIG. 1

Most of the older types of electric elevators employed a starting resistance which was cut out by means of a contact, on the end of an arm, sliding over a series of fixed contacts connected to the resistance. This is the plan used for ordinary motor starting boxes, and the same idea was carried out in connection with elevators, various methods being used for moving the arm. Sometimes this was done by means of a shipper cable running to the car, but more often it was accomplished by means of a solenoid. In any event, it was soon found that the sliding contact gave considerable trouble unless the contact plates were watched carefully and kept in good condition. With motors of any considerable size, requiring a large current, a burning action is specially liable to occur so that the so-called "magnet" system of control, which has come into extensive use, has been brought out to do away with these troubles. In brief, the magnet system replaces the contact plates and sliding contact, by a series of electromagnetic switches which close in succession as the motor comes up to speed, and thus cut out the resistance. It has been found in practice that a large number of resistance sections is not necessary with this system. In the rheostat it is necessary to have quite a large number of contact plates in order to keep down the voltage between the plates, and thus reduce sparking, while with the electromagnetic switches this requirement does not have to be met.

Also, with the magnet system the action is automatic, the resistance not being cut out until the counter E. M. F. of the motor has risen to the point where the motor is able to take care of an increase in applied E. M. F.

The principle of the system of magnet control will be understood by referring to Fig. 1. This is intended merely to illustrate the method, and does not represent the system as applied to an elevator. A is the main switch which, when in the position shown, causes the motor M to start up in one direction, and when thrown down to the position indicated by the dotted lines, reverses the current in the armature and, therefore, makes the motor run in the opposite direction. The switch has three blades b_1, b_2, b_3, and six fixed contacts *1*, *2*, *3*, etc. R is the starting resistance divided into two sections a and b which are cut out by the electromagnetic switches S, S' as the motor comes up to speed. The coils of S, S' are connected in series across the terminals of the armature, and the positions of the armatures a', a'' are adjusted so that a' will close with a smaller current than a''. When the switch A is closed, armatures a', a'' are as shown in the figure, and the main current flows through both sections a and b of the resistance. As the motor comes up to speed, the pressure across the armature terminals c d increases, thus increasing the current through S and S'. When this current has become large enough to operate S, a' closes, making contact at z' and thus cutting out section a of the resistance. As the speed increases further, S' operates, thus cutting out section b by closing the contacts at z''. The path of the current is indicated by the arrowheads. Usually four or five resistance switches are sufficient to give an elevator a smooth start, and in the regular magnet controllers the starting and reversing switch A is replaced by two or more electromagnetic switches which accomplish the same end, and which can easily be operated from the car. In some cases one or more of the resistance switches are under the control of the elevator oper-

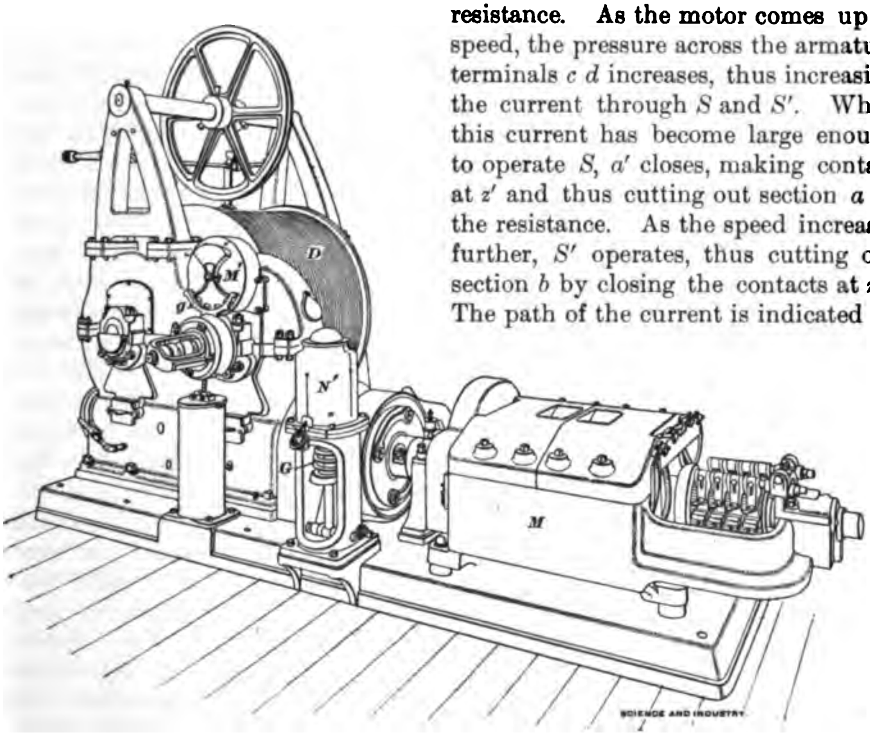


FIG. 2

ator, instead of operating automatically.

Fig. 2 shows an Otis electric elevator as used with the magnet system of control. The drum D is driven, through worm gearing, by means of the motor M. N' is the solenoid that controls the band brake; M' is the stop-motion switch operated by a traveling nut on the worm-gear shaft. This switch stops the motor when the car approaches the limit of its travel in either direction. Outside of these two devices, it will be noticed that there are no electrical devices on the elevator machine; the controller is an entirely distinct piece of apparatus. When the solenoid N' is energized, the brake is released, and when N' is demagnetized, the brake is at once applied by spring G.

Fig. 3 is a larger view of the stop-motion switch M'. When the car approaches the limit of its travel, the segmental gear g swings over, carrying with it the arm a inside the casing. This arm is provided with contacts which rub on the arcs b b, and when the arm swings over, the contacts on one side of the arm slide on to the insulating pieces, thus breaking connections which result in the stopping of the car. The action of this switch will be understood when we consider the connections for the controller.

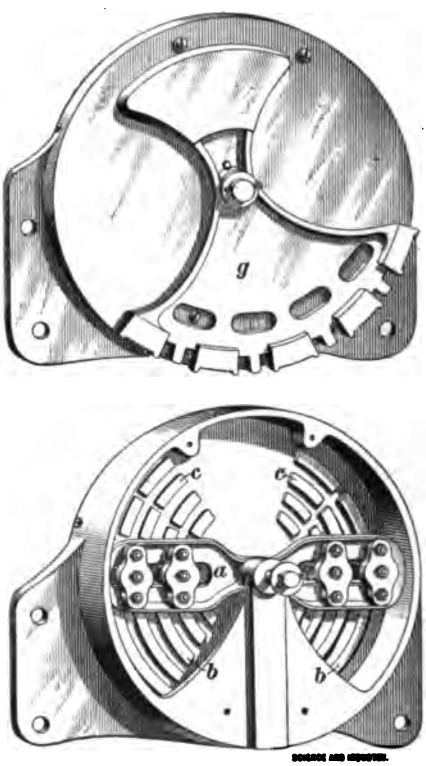


FIG. 3

Fig. 4 shows the operating switch that is used in the car, the cover being removed so as to show the working parts. The operating handle h is shown in the central or "off" position, and is held in this position by a spiral spring s. When the elevator is to be operated, h is pulled out against the action of a spring until shoulder k clears the notch in which it rests. When the handle is moved, say to the right, the contact piece b first makes connection with contact finger *2*, then *3*, and finally with *4*, in which position the elevator is running at its highest speed. The current which this switch has to handle is very small, only about $\frac{3}{4}$ ampere, but this is sufficient to operate the switches on the controller. The switch is connected to the controller by means of a flexible cable, and as the operating current is small the wires in this cable do not need to be large.

Fig. 5 shows the Otis No. 6 magnet controller. All the working parts are mounted on a slate board supported on an iron framework. A' and B' are the switches that control the direction of motion of the car. Switch C' closes the main circuit. Switches *1*, *2*, *3*, etc., control the resistance. Each switch consists of a solenoid which, when excited, draws up its core e and each core carries one or two circular contact disks, as, for example, d d'. These disks

make contact between fingers mounted on the board as shown at *f f'*, and some of the switches are provided with upper and lower contacts as shown at *1*, so that when the core is drawn up contact is made between the two upper fingers, and when it drops contact is made between the lower fingers. Each finger is provided with an auxiliary carbon contact *x*, which makes contact with the disk before the copper contact, which is placed behind it. Also, when the disk drops, the carbon contact does not break connection until after the copper contact has left the disk. Any burning or arcing that takes place is, therefore, confined to the carbon contacts which are easily renewed. If burning took place at the copper contacts, the switches might stick, and thus fail to operate. The movements of the switch cause the disks to work around so that what little burning takes place is distributed around the whole disk. The whole construction is so simple and substantial that there is little chance for the controller to give anything like the trouble experienced with many of the older rheostat types. On the 500-volt controllers, magnetic blow-out coils are provided on the main switch *C'* so that the arcing is reduced to a minimum.

Before taking up the connections for the controller, a few words with regard to the motor used for these elevators will not be out of place. The motor is provided with three field windings called the shunt, series, and extra field coils. The shunt winding supplies the field when the motor is working at full speed. The series winding is used at starting in order to supply a strong starting torque or effort, and thus get the car quickly under headway. The extra field also helps to a certain extent to provide a field at starting, but its principal function is to maintain the field when the motor is being stopped. When the elevator is to be stopped, the current is cut off from the motor and the band brake is applied. In addition to this, a dynamic braking action is provided for by allowing the motor to act as a generator by sending current around through the extra field. This winding, therefore, helps to keep up the field at stopping, and thus brings the motor to rest much more quickly than if the band brake alone has been applied.

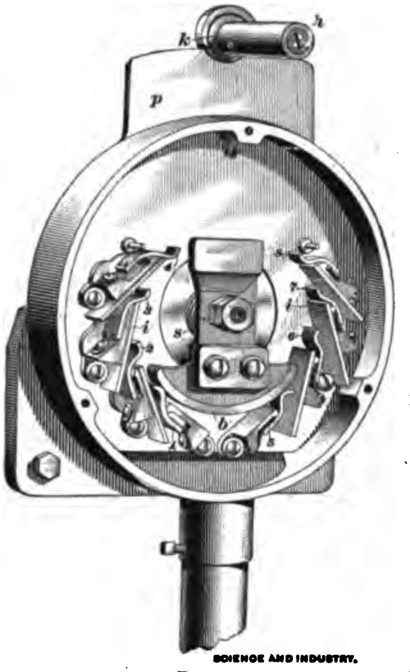

SCIENCE AND INDUSTRY.
FIG. 4

Fig. 6 is a diagram of connections illustrating the operation of the controller shown in Fig. 5. Corresponding switches in the two figures are lettered alike. The path of the main current is shown by the heavy lines and arrowheads, while that of the operating current is indicated by the light lines and arrowheads. Suppose switch *P'* to be moved to the left until *z* makes contact

with u. The operating current then flows in at x, which is connected to the + line wire, and takes the path indicated by the arrowheads through the coil of switch B' to y and thence to the — line. This operates B' and makes connections such that the motor raises the elevator as soon as the main circuit is closed. This is done as soon as switch P' is moved over far enough

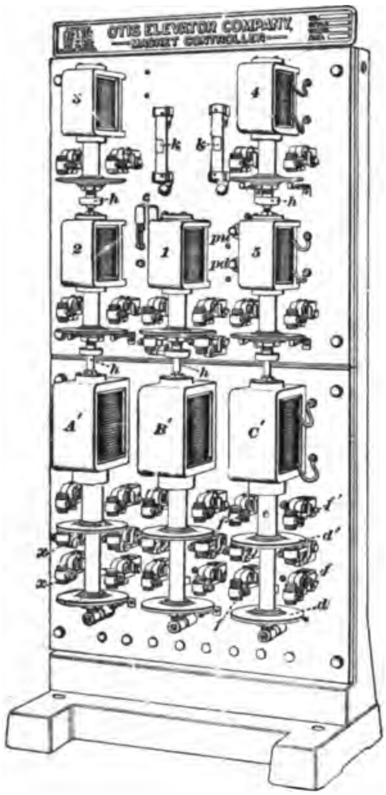


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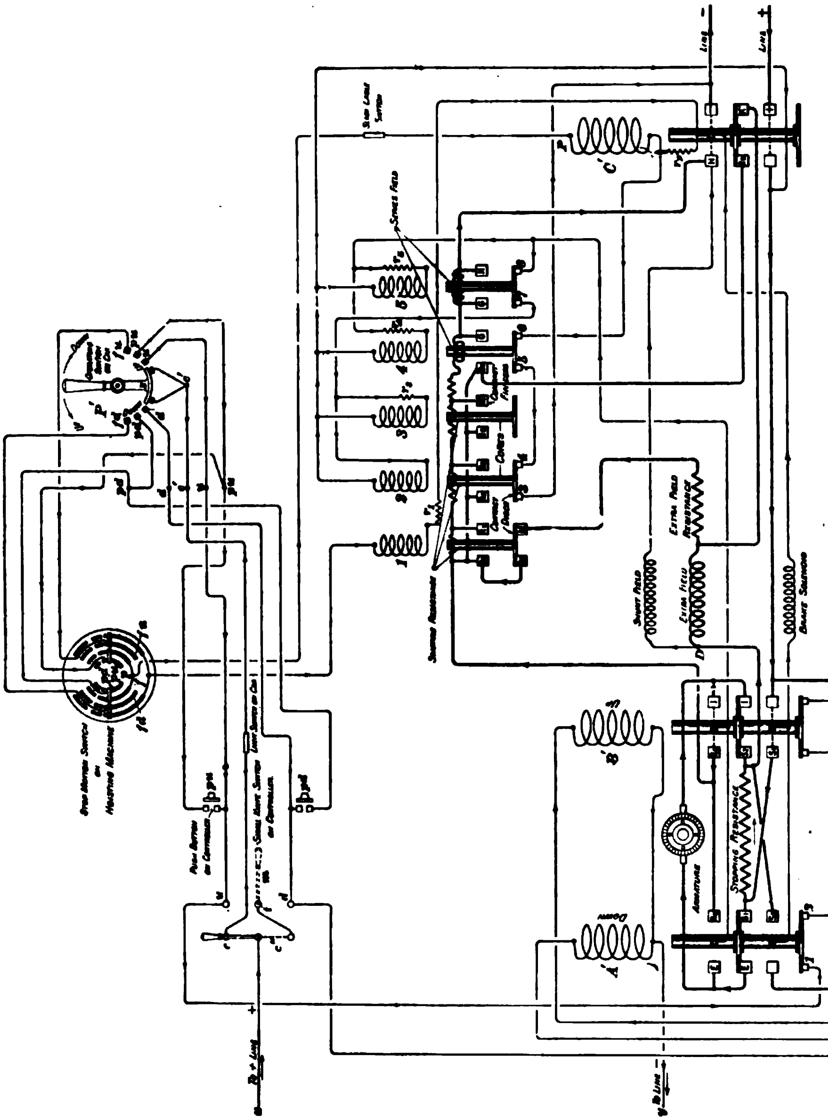
FIG 5

to bring z in contact with $p\,u$, and allow the current to flow through the coil of C', thus lifting its core and allowing current to flow through the starting resistance, series field, and extra field as shown by the heavy arrowheads. As soon as C' is lifted, current also flows through the brake solenoid as indicated, thus releasing the band brake. The path of the main current after C' has operated is as follows: + line — to contact S_1 on switch B' — to S_1 on A' — E — through armature — I — $R\,o$ — through whole of starting resistance — through series field coils — H — to — line. After the current reaches point S_1 on switch A', part of it may take the path S_1 — through stopping resistance — S_2 — D — through extra field — through extra field resistance — to M on switch *1* — $R\,o$, and so on to the negative line. As soon as switch C' closes, current flows through the shunt field as indicated. By tracing out the connections it will be seen that the coils of switches *2*, *3*, *4*, and *5* are now connected across the armature terminals, and as the motor comes up to speed these switches will operate one after the other, the voltages at which they operate being adjusted by means of resistances r_3, r_4, r_5. When *2* closes, two sections of resistance are cut out and *3* cuts out the remainder of the resistance; *4* and *5* cut out the series field coils, as the motor is by this time well under way, and they are no longer needed. When the operating handle is moved to the $f\,u$ "fast up" point, switch *1* operates and cuts out the extra field, thus weakening the field of the motor and making it run as a plain shunt-wound machine.

When the elevator is to be stopped, P' is moved back from the $f\,u$ position, thus allowing switch *1* to drop and placing the extra field in series with the extra field resistance, across the armature. This strengthens the motor field and slows the machine down. When P' is moved back from the $p\,u$ position, switch C' drops, thus cutting off the current from the line and also from the brake solenoid. This sets the brake, and as points $R\,o$ and K' are connected by the dropping of C' the extra field resistance is cut out, and the motor,

acting as a dynamo, is able to set up a powerful current through the extra field coil and stopping resistance, thus exerting a dynamic action which together with the band brake soon brings the motor to rest. If P' is moved from the u position, switch B' drops, but it is not necessary to operate the direction-controlling switches every time the elevator is stopped. For example, if the elevator were coming down and making stops at the several floors, it would only be necessary to move the switch back from the p u position, thus leaving the direction-controlling switch up during the trip.



SCIENCE AND INDUSTRY.

FIG. 6

CLEARANCE—II

H. ROLFE

How Clearance Is Expressed—Has to Be Known When Constructing Preliminary Diagrams—Its Effect on the Expansion Curve—Ratios of Expansion

We remarked in a previous article on this subject that the term clearance has a double meaning. The one, *piston clearance*, we have already described and explained the necessity of; this is simply a linear quantity. The other, or *cylinder clearance*, is a cubic quantity or a volume. It is the volume of the space that exists between the valve face and the face of the piston, when the latter is at the end of its stroke. It thus comprises the volume of the steam port and a portion of the cylinder whose length is the piston clearance. It is expressed as a percentage of the cylinder volume proper, or what amounts to the same thing, a percentage of the stroke. Thus, an 18″ × 24″ cylinder has a volume of 6,105 cubic inches; this is better spoken of as the piston displacement, meaning the amount of space swept out or displaced by the piston during one stroke. Assuming the piston clearance to be $\frac{5}{16}$-inch and the volume of the steam port 200 cubic inches, the latter is equivalent to the volume of an 18-inch cylinder of length $\frac{200}{6,105} \times 24 = .7862$ inches. Thus, the total clearance is equal to a length of cylinder $= .3125 + .7862 = 1.10$ or nearly $4\frac{5}{8}$ per cent.

Now in designing engines, particularly high speed ones, it is desirable to know just what the rotative effort is at any part of the stroke. To ascertain this, each crank effort (if more than one crank) is plotted for different crank angles, and the combined effect considered. The steam pressure has therefore to be known for each position of the crank. If the engine was built and running, indicator cards would serve to show this; the effective pressure on the piston at each position being there shown. If the engine is not yet made, a preliminary tentative diagram is plotted, which will show approximately what will subsequently obtain; this is done for different cut-offs. Assuming a certain boiler pressure, allowance is made for a drop in pressure before reaching the admission valve; also a certain amount for wiredrawing during admission. Then, having the volume and pressure at cut-off, the pressure at any subsequent point of the stroke can be computed, making an estimate of the probable back pressure.

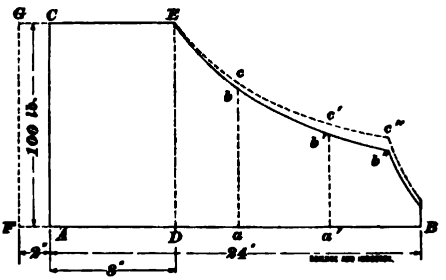
To show the difference in the steam pressures when clearance is and when it is not taken into account, we refer to the accompanying figure. For emphasis, we will consider the volume as being $\frac{1}{12}$ that of the piston displacement, or $8\frac{1}{2}\%$; it ranges really from 3 to 10%; $4\frac{1}{2}$ to 5% is good practice for ordinary engines. In Corliss work, where the valves are placed at the ends of the cylinder, the ports are reduced in length, and so the clearance is much diminished.

Suppose then, a cylinder 24 inches long and with $8\frac{1}{2}\%$ clearance; assume a cut-off at one-quarter stroke. The theoretical diagram of expansion is as shown in full lines, whereas when taking clearance into account, it is as shown in dotted lines. The law of expansion of dry saturated steam, as given by

Note.—The first part of this article appeared in the February, 1902, number.

Rankin is expressed thus: $p\,v^{\frac{17}{16}} =$ a constant. This means that as the volume increases, the pressure falls at such a rate that the product of the pressure and the $\frac{17}{16}$ power of the volume is always the same. (Later investigation gives 1.0646 instead of $\frac{17}{16}$.)

This relation between the volume and pressure approximates to the much simpler one of "$p\,v =$ constant." This is easier to handle and has been used in plotting the curve of expansion in the figure, which illustrates the effect of not taking the clearance into account. Here $A\ B$ is the nominal length of the cylinder (the length of stroke, in fact), and $A\ C$ the initial pressure; E is the point of cut-off. As a matter of fact the cut-off pressure $D\ E$ will be less than the initial pressure $A\ C$, due



in some measure to the restricted area of throttle and steam pipe, and also, and in much greater degree, to the diminished area of port opening as the valve approaches cut-off. In constructing these preliminary diagrams, we can assume a straight steam line $C\ E$, however. At any subsequent point a of the stroke, the pressure $ab = \frac{A\,D}{Aa} \times A\,C.$ If $A\,D$ is 8 inches, and a is at half stroke, the pressure $ab = \frac{8}{12} \times 100 =$ 67, taking 100 lbs. as the initial steam pressure. At a', 18 inches from A, the pressure $a'\ b'$ is $\frac{8}{18} \times 100 = 44$. At b'', the exhaust is supposed to open. Next consider the effect of using clearance. Set off $A\ F = \frac{1}{12} \times 24 = 2''$, and draw the vertical line $F\,G$. The volume of steam in the cylinder when the piston reaches D is now $\frac{10}{8}$ of what it was on the first supposition. The pressure at a therefore will be $\frac{10}{14} \times 100 = 71$, and that at a' is $\frac{10}{20} \times 100 = 50$. Thus, the steam pressures are really higher than appeared before. (There is the back pressure to be taken into account, but we are merely dealing here with the expansion curve.) Now, the existence of this clearance space is often spoken of as a loss. When an engine is running slow and working steam full stroke, the clearance does involve a direct waste of steam. Thus, imagine the steamport open to boiler pressure until the end of stroke is reached, and that exhaust continues until the end of the return stroke, the pressure falling to zero, and that then readmission begins. Then, if area of piston is 2 square feet, and the stroke is 2 feet, we consume 4 cubic feet of steam in propelling the piston 2 feet, assuming there to be no clearance. If, however, the clearance volume is equal to $\frac{1}{12}$ of the piston displacement, we use $\frac{13}{12} \times 4 = 4\frac{1}{3}$ cubic feet of steam at every stroke, and yet the pressure on the piston is no greater, and no greater amount of work has been done. Now, the above is just what would occur in a steam engine in its most elementary and primitive form. In practice, however, mechanical reasons and a regard to economy demand that we take advantage of the property of expansion, and also that we apply a "cushion" at the end of the stroke, in order to arrest more smoothly the momentum of the moving parts and so avoid sudden shocks. This cushion can be obtained either by preadmission or by early closure of the exhaust port; in actual practice we do both. Now, supposing we employ only the former, it is clear that the whole of

the clearance space has to be filled before any effect is produced on the advancing piston, and this amount is wasted. If, however, we close the exhaust early, the steam in the clearance space is compressed (sometimes nearly to admission pressure), and therefore is already filled with steam when the port is again opened to the boiler. Thus, this space is less objectionable at high speeds and expansions.

In steam engine design, the question of ratio of expansion is a constantly recurring one, and it is here that the item of clearance must be considered. Thus, in our example, the nominal ratio of expansion is $\frac{24}{8}$ or 3, whereas really it is only $\frac{26}{10}$ or 2.6, $13\frac{1}{3}$ % less. It will be seen, then, that increased clearance means less expansion and a greater pressure at release; also less pressure at the end of compression—with a given point of exhaust closure. Broadly speaking an increase of clearance is accompanied by increased water consumption, that is, increased steam consumption. Excessive clearance is also objectionable in condensing engines, as the condensation is then less perfect owing to the steam that remains in the ports and passages of the cylinder.

METHOD OF TESTING, AND PERFORMANCE OF STEAM BOILERS

W. B. GUMP

STEAM boilers may be divided into three general classes: (1) stationary, (2) locomotive, (3) marine. As this article is intended only as a general description, the former class will be the one referred to.

By boiler performance is usually meant the physical phenomena which take place in the operation of steam boilers. The term performance used commercially means the capacity for generating steam and the economy of fuel, since these values are always desired when a test is to be made.

When a boiler is tested there must be at the outset a definite object in view. It may be for the purpose of ascertaining the evaporative qualities of a certain fuel, or the capacity for generating steam, or both.

In general it may be said that among the most important items we seek is the determination of the amount of water evaporated per pound of coal. Other fuel may, of course, be used, but coal is the universal standard and will be considered here exclusively. The method of testing is specific for each case, due to the inherent conditions. As regards locomotive boilers, it may be said that they are very inefficient and are usually tested only for strength and capacity for generating steam.

Stationary boilers may be subdivided under two heads, (1) fire tube, commonly called tubular boilers, and (2) water tube. In the former the water circulates around a large number of tubes whose ends are expanded into the ends of the boiler shell, or tube sheet, the hot gases from the fire passing through the tubes and up the chimney. In the water-tube type the water circulates through a series of tubes, and the flames and hot gases play beneath and around the tubes.

In each class there are certain advantages, and each has its disadvantages. It is generally agreed that the water-tube type is less liable to cause

disastrous explosions, but it is much more expensive and is generally more trouble to clean.

The fire-tube type is more easily installed, is cheaper, and when a good setting is made gives very satisfactory results.

There has been much controversy as to which surface of a steam boiler should be reckoned as heating surface; that which is in contact with the water, or that which is in contact with the fire. The latter has found the most favor, so we shall frame our definition of heating surface as that which is in contact with the fire.

Before describing a test, let us understand what is meant by the efficiency of a boiler. The efficiency of a boiler, as regards the majority of tests is, in reality, the combined efficiency of boiler and furnace, since it is the heat obtained as steam, divided by the heat evolved by the combustible.

The efficiency of a furnace alone would be the heat used, divided by the total heat supplied, but in a boiler furnace the heat supplied is necessarily greater than the heat absorbed for evaporating the water. From this it may be seen that the efficiency of the boiler alone would be the heat actually used in evaporating the water to generate steam at a given pressure, divided by the heat supplied to the heating surface. The distinction between these two efficiencies should be borne well in mind in order to have an intelligent conception of the following description. As the description is to treat the subject of boiler testing in a general way, let it be understood that what follows will pertain to commercial efficiency, which, as was stated, includes boiler and furnace.

In order to have some basis upon which to rate a boiler, it has been decided to make the standard of comparison according to the rate of evaporation. Unfortunately, the term horsepower has come into use, and it is not out of place to state here that the term is a very misleading one. A boiler cannot of itself develop power: it is a means of producing power by the energy stored up in it, but the term horsepower as applied to boilers is used only because of the lack of a better and more appropriate term. It is necessary to add that the horsepower of a boiler and that of an engine are entirely separate and distinct. It will be apparent from the following why they cannot bear any relation to one another. A steam engine uses anywhere from 12 to 20 pounds of steam per horsepower per hour. The rate of evaporation of a boiler depends upon many conditions and is quite a variable quantity, so that no fixed relation can possibly be established between the engine and boiler. We must have some standard, however, and as there is no better means of comparison than by a fixed rate of evaporation, it has been decided that one boiler horsepower is measured by the evaporation of 34.5 pounds of water per hour into dry saturated steam from and at 212° F.

Different boilers generate steam at different pressures, and the feedwater is received at different temperatures. We must therefore find the equivalent evaporation in order to compare their relative performances.

It has been found convenient to employ a mathematical quantity called the "factor of evaporation," and by multiplying it by the actual evaporation we obtain what is known as the equivalent evaporation. The equivalent evaporation is the evaporation per pound of combustible which would have been produced from dry steam at 212° F. and at atmospheric pressure.

If W = weight (in lb.) of water evaporated;

H = total heat of steam above 32° at pressure of actual evaporation;

T_f = observed temperature of feedwater;

E = equivalent evaporation from and at 212° F.; then

$$E = W\left[\frac{H - T_f + 32}{966}\right] \qquad (1)$$

since 966 heat units are required to convert 1 lb. of water at 212° into steam at the same temperature.

The quantity $\left[\frac{H - T_f + 32}{966}\right]$ is the factor of evaporation, and it increases directly as the steam pressure increases, as will be seen by the tables. These tables giving factors of evaporation have been computed in order to save the trouble of stopping to calculate them when making a test.

From the definition of boiler horsepower it may readily be seen that we may calculate the horsepower of a boiler using steam at any pressure, by the following expression:

If F = factor of evaporation, or $\left[\frac{H - T_f + 32}{966}\right]$;

X = % of dryness of steam (by calorimeter);

W = weight of water evaporated;

T = time in hours; then

$$\text{H. P.} = \frac{W\,X\,F}{34.5\,T}.$$

The value of X is obtained in the regulation manner by means of the calorimeter, which should be connected as close to the boiler as possible. The value for W is formed by weighing all the feedwater that goes into the boiler during the test, the water level in the gauge glass being kept the same; thus it is obvious that the amount fed into the boiler must equal the amount evaporated, since the level has been kept constant.

The amount of time required for testing a boiler should be not less than 10 hours, and 24 hours is recommended as likely to give more accurate results. Strict attention to business is imperative when a test is once under way, since a single error in observation may necessitate beginning all over, and will cause great annoyance all around.

When a boiler is to be tested it should first of all be thoroughly inspected externally and internally; the setting should be looked over, the shell and flues examined, and finally the chimney very carefully gone over. The point of importance regarding the chimney is examination to discover any air holes which may be present; by air holes is meant crevices or orifices of any kind which permit cold air from outside the chimney being sucked in and destroying the effects of the draft by lowering the temperature of the hot gases. A lighted tallow candle is as simple a means of detecting air holes as any, and when the flame is held near one of these holes the current of air issuing therefrom will distort the flame immediately. With reference to the boiler shell and flues, we wish to detect any rust which may be present, and any pitting, besides scale deposits which may ordinarily be unnoticed.

The proceedings just mentioned are only those comprising ordinary boiler inspection, yet they are often slighted, and their neglect may ultimately cause a forfeiture of the engineer's position, to say nothing of paving the the way for an explosion.

After the boiler is believed to be in trim, the next task is to set about to take all necessary measurements. These comprise general dimensions, as length, breadth, and height of boiler setting, and width and height of chimney. The

other dimensions, and the ones of most concern, are the area of grate surface, the water-heating surface, and the superheating surface. For a fire-tube boiler the heating surface will be the inside area of all the tubes plus the outside area of the shell below the brickwork; and for the water-tube type it will be the outside area of all the tubes plus the outside area of the shell below the brickwork. There is practically no superheating surface to be accounted for in horizontal boilers. In the case of vertical boilers this is reckoned as the heating surface above the water and in contact with the steam, thus reheating the saturated steam which has been formed, hence the name superheating surface.

Now, it is apparent that a good many values are sought in testing a boiler, and in order to give a satisfactory account of such a test let us first tabulate the usual items, and following this describe how they are found. Before proceeding with the table it is necessary to state that the conditions throughout the test must be kept uniform as far as it is possible. By uniform condition is meant that the draught should be maintained at the same pressure, the firing regular, and any feature which would materially affect the rate of evaporation must be watched closely.

It is found necessary in certain kinds of tests to make an analysis of the flue gases. This is done usually by some form of Orsatt's apparatus, which consists of a system of syphons and glass tubes containing chemicals which respectively absorb from the chimney oxygen, carbon monoxide, and carbon dioxide. The amount absorbed by each in a given quantity of flue gas is measured, and the percentage of gases forming the products of combustion is thus obtained, which shows the true condition of the furnace.

In the ordinary commercial test it is not necessary to analyze flue gases, and without taking this up further we shall look at the following items; it being remembered that the results are to be obtained from the average of a large number of readings for each item:

Results of the trial of..............................
Boiler..............................
To determine..............................

(1) Date of trial..............................
(2) Duration of trial..............................
(Space for complete description of boiler).

Dimensions

(3) Grate surface .... wide ....long............ area
(4) Water-heating surface ....
(5) Superheating surface ....
(6) Ratio of water-heating surface to grate surface ....

Pressures

(7) Steam pressure in boiler by gauge..............................
(8) Force of draught in inches of water..............................

Temperatures

(9) External air ....
(10) Escaping gases ....
(11) Feedwater ....

Fuel

(12) Total amount of coal consumed, including equivalent of wood used in starting fire. 1 lb. of wood is equal to 4 lb. of coal..............................
(13) Moisture in coal ....
(14) Dry coal consumed ....
(15) Total refuse dry.................. lb. ....
(16) Total combustible. Item (14) less (15) ....

Results of Calorimeter Test

(17) Quality of steam.

Water

(18) Total weight of water pumped into boiler and apparently evaporated, being corrected for inequality of water level, and of steam pressure at beginning and end of test.......
(19) Water actually evaporated, corrected for quality of steam ....
(20) Equivalent water evaporated into dry steam from and at 212° Fahrenheit ....
(21) Equivalent water evaporated into dry steam from and at 212° per hour ....
(22) Equivalent water evaporated per pound dry coal from and at 212° ....
(23) Equivalent water evaporated per pound combustible ....

Rate of Combustion

(24) Dry coal actually burned per square foot of grate surface per hour ....

Rate of Evaporation

(25) Water evaporated from and at 212° per square foot of heating surface per hour..............................

Commercial Horsepower

(26) On basis of 34½ pounds water evaporated at atmospheric pressure from and at 212° F.
(27) Horsepower, builder's rating at.................. square feet per horsepower ....
(28) Per cent. developed above or below rating ......
(29) Efficiency of boiler as determined from results ....

If the previous description has been

gone over carefully it will readily be seen that most of these values may be obtained without difficulty. Those which are more difficult will now be described: Item (4) is a problem in arithmetic, needing no description; in item (8) we wish to ascertain the draught of the chimney, which is usually given in terms of a column of water. This is measured by a glass tube called a manometer, and is simply a **U**-shaped tube containing some four or five inches of water when held in a vertical position. One end of the tube is coupled to a small rubber hose which leads into the lower part of the chimney, the other end of the glass being open to the atmosphere. It is evident that the chimney gases are lighter than the atmosphere by an amount which is indicated by the difference in the water level in the arms of the tube—in other words, the greater the draught the greater the difference in water level.

Item (10) refers to the temperature of the hot gases as they leave the uptake, and pass into the chimney. Unless a special thermometer is preferred, a copper ball pyrometer may be used; care is necessary, however, in order to get good results.

A piece of copper, usually spherical in shape, is carefully weighed and then is suspended in a position best adapted for exposing it to the hot gases. When it has become thoroughly heated, it is quickly taken out and plunged into a known quantity of water whose temperature and weight have been recorded; then,

$$S\,W(X-T)=W(T-t),$$

from which $X=\dfrac{W(T-t)}{WS}+T$

where $S=$ specific heat of copper;
$W=$ weight of ball;
$X=$ temperature of ball;
$T=$ final temperature of water;
$t=$ initial temperature of water.

The feedwater must first pass through two tanks, the same as are used in an engine test. From the weighing tank the feedwater should be allowed to pass into another stationary tank; a large barrel will serve nicely. Here the temperature is recorded, the water then being fed directly into the boiler.

Before proceeding with the values for fuel, it is well to say something about the heating value. This is not tabulated, because in the majority of cases an average value is accepted as being accurate enough for ordinary purposes. A great many tests show that coal from each locality has a corresponding heating value.

If a heating value is not assumed, it is then necessary to make a calorific test with some form of coal calorimeter, and let it be emphasized here that the results of a coal calorimeter test outside of expert hands are little better than worthless.

Roughly, 13,000 B. T. U. per pound of coal may be taken as an average, but the value should be taken from data relating to the coal obtained in that section of the country. Dividing coal into two classes—anthracite and bituminous—we may assume, roughly, 12,000 B. T. U. per pound for anthracite and 14,000 B. T. U. per pound for bituminous.

A good coal should not contain more than 8 to 10 per cent. ash. The coal used should be weighed very accurately, as it is a basis for finding several other items. Where coal handling and weighing apparatus is not at hand, the coal must be weighed on some other convenient form of scale, the receptacle being carefully weighed, and the weight of it deducted each time. The moisture may easily be determined by weighing a given amount of coal, then heating it until it is dried out, and again weighing. In order to do this accurately the

sample of coal should be pulverized, as it exposes more surface, and evaporates all of the moisture contained.

Then,

$$\text{Per cent. moisture} = \frac{W - w}{W} \times 100$$

where W = original weight of the sample of coal and w = final weight. Having found this, the next item is easily found.

It is obvious that the ashes must be carefully weighed and recorded. This will give us a means of finding item (15).

The value for (17) is found in the ordinary way by some form of steam calorimeter.

Item (18) is found by weighing all the water fed into the boiler and correcting it for any difference in water level at the end of the test. If the steam pressure has changed, the weight which is deficient or in excess must be reckoned according to the weight per pound of water at said steam pressure and temperature. This is because the density of the water varies with the pressure and temperature.

Item (19) is the water apparently evaporated minus the percentage of moisture as shown by the calorimeter.

The value for item (20) is found by substituting results in the formula given at the beginning of this article.

The remaining values follow in natural sequence and are only arithmetical operations.

The success of the test will in a large measure be shown by the final comparison of the results with those of the builder's rating. This is especially true in regard to a test which follows out the builder's specifications. Scarcely ever does it follow that the test will show an efficiency equal to that claimed by the builders. They usually employ experts in making their own tests, and the conditions under which these tests are made are the most favorable that can be had.

In conclusion, we may add that economy of fuel depends principally upon three things: the completeness with which the coal is burned in the furnace, the proper regulation of the air supply, and the thoroughness with which the boiler itself absorbs the heat generated in the furnace. The capacity of a boiler may increase with increase of economy when the latter is due to more thorough combustion of the coal or to better regulation of the air supply, or it may be increased at the expense of economy when the increased capacity is due to overdriving, causing an increased loss of heat in the chimney gases.

The relation of capacity to economy is a complicated one, and there are so many variables that, so far, no definite formula has been devised.

By selecting the highest results of different rates of driving obtained with anthracite coal in the Centennial tests, we find the evaporation as follows: Pounds of water evaporated from and at 212° F. per square foot heating surface per hour, 1.6, 1.7, 2, 2.6, 3, 3.5, 4, 4.5, 5, 6, 7, 8.

It is shown that beyond a rate of evaporation of 3 or 4 pounds per square foot of heating surface per hour there is a decrease in economy.

Pounds water evaporated from and at 212° F. per pound combustible, 11.8, 11.9, 12.1, 12.05, 12, 11.85, 11.7, 11.5, 10.85, 9.8, 8.5.

The general law for semi-bituminous coal follows that of anthracite.

In general it may be said that the best results are produced in a boiler where the temperature of the escaping gases is the least.

SCIENCE IN LACING BELTS

Description of Easy Processes

As in all the other arts in the mechanical and engineering line, the science of lacing leather, rubber, canvas, and other kinds of belting

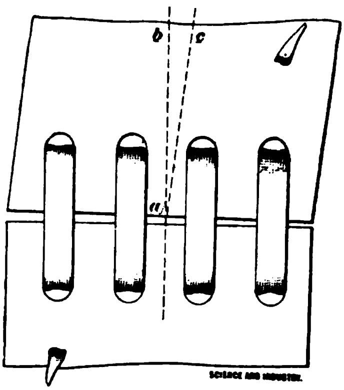


Fig. 1

for the transmission of power, requires practice and planning. In former days, when the average machinery in the manufacturing establishment was not operated at anywhere near the speed obtained in the machines of today, the science of belt lacing did not amount to so very much. But these days passed away some years ago, and in the present age the machinist and the engineer find it quite necessary to bring their belt unions up to the date of the machinery to be belted. We will, therefore, devote this article to a narrative of belt lacing. The writer will first point out some of the common defects in belt joints as witnessed in the everyday work of the shop and mill. In Fig. 1, for example, we see a good lacing made in the belt, but the ends of the belt having been improperly united, the union becomes ineffective. The joint was made without regard to evenness of the butts. A straight line is extended through the joint and is indicated *b*. This line may extend through the middle of the lower section of the belt, but not through the upper. In the upper portion the belt center takes a deflection along the line *c*, beginning at the point *a*. The result is that we have a wabbly belt, that will run from one side of the pulleys to the other. The belt will slip and give endless trouble. Perhaps the belt will be condemned, and it will be stated that the leather is poor. All that is needed is to open the union, place the straightedge on the ends of the belt, mark off the holes straight across, and punch and lace accordingly. Also cut off the ends on the correct line indicated by scratching, with the straightedge as a guide, and then there will be no danger of getting a lacing like that shown in this sketch.

We will next call attention to the style of belt lacing illustrated in Fig. 2. Apparently this form of lacing is effective. Many of the best power engineers use this style, and it is good for ordinary work. But those who use this splice may often wonder why it is not a lasting union. The reason is that although the joint is strong for quite a

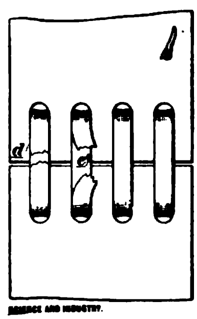


Fig. 2

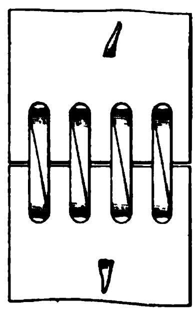


Fig. 3

while, any excessive service will surely produce premature wear of the outer layer of lace, as at *d* and *e*, and these places which are worn thin will tear

out. The fact is, that although two or three laps of good lace leather are used, only the outer lap gets the wear and tear on the face of the wheels. The long flat surface makes a good facing for wear, and the leather is soon reduced to a thin and broken condition, and the laces pull out and relacing is required. To overcome this trouble, the style of lacing shown in Fig. 3 has been introduced and is used with good results for general operations. The holes are punched the same, but instead of using one end of the lace and working over and over through the holes, as in Fig. 2, two ends of the lace are taken, and one is drawn in over the other, from the

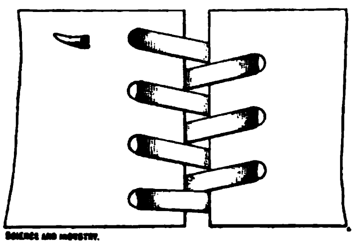


FIG. 4

opposite side, as shown. Thus two laces are presented, or parts of laces, at the same time to the wear of the pulleys, with the result that the life of the lace is preserved for a much longer period.

Fig. 4 illustrates the so-called hinge formation of splice, which is used chiefly by mechanics and engineers in running small wheels at high rates of speed. Sometimes the union is made to economize in belt lacing, for it can be seen that a short piece will go a considerable ways. One piece of lace is worked with and inserted at one end, and, after passing through the hole, is dropped down between the ends of the belting, to come up on the other side in the opposite hole. The operation is repeated back again and over and over until the width of the lacing is finished.

The lacing in Fig. 5 is designed for heavy work; that is, heavy work for belts of average width. The idea consists in a distribution of the strain quite

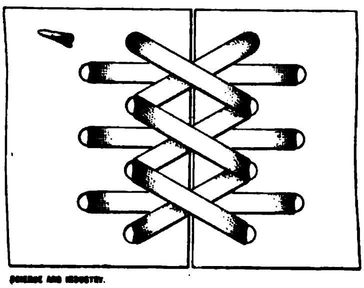


FIG. 5

freely, so as to bring the pull on the union at as many different points as possible.

The first operation consists in squaring off the ends of the belt, and this ought to be done only on a line marked with a scratch awl and a straightedge. Guess work at this point will ruin the whole splice. Use the straightedge to get the line true; then again with the straightedge mark off the first row of holes, say about an inch from the ends, to be followed with a marking of the next row another inch back, or a little more or less, according to the width and weight of the belting. It is a good plan, also, to mark off the distances

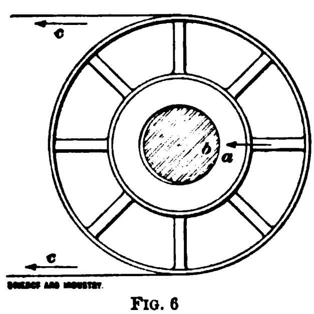


FIG. 6

between each of the holes, so as to get each hole in position to correspond with its mating hole on the other half of the belt. Now select a good, evenly

cut, and well-seasoned lace leather and proceed to lace, following the plan.

The next illustrations deal principally with the pulleys, shafts, and

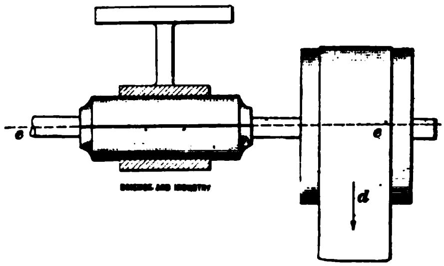


FIG. 7

hangers. Fig. 6 is a sketch given for the purpose of indicating the character of the wear upon the sleeve of the loose wheel. Suppose that the belt draws in the direction signified by the arrows *c*, *c*. Then, after months of running under these conditions, the draft in that direction is very liable to produce wear of the shaft or bushings, as at *a* and *b*. When this happens, the shaft and wheel become more and more wabbly in course of service, until the conditions become such that the wheel hub must be rebushed. This trouble often occurs in connection with belts which reach from one shaft to another for the purpose of power transmission. If the belt is heavy, the tendency for wear upon the parts

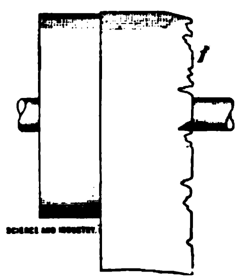


FIG. 8

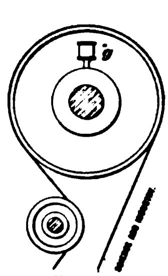


FIG. 9

of wheel linings is still greater. In the case of very tight belts, the parts often become heated, due to the excessive strain for a long period. Machinists equalize the strain upon the pulleys as much as is possible by the use of idlers, guide wheels, etc.; still it is hardly possible to avoid the trouble. Consequently we have frequent instances of shafts and pulley hubs worn on the draft side, and a renewal of parts made necessary.

In Fig. 7 is shown a familiar case of the belt pulling the carefully aligned shaft down and out of true. This is often seen in shops and mills. The shaft is adjusted to the hangers perfectly true. But it so happens that there is a wheel required at the outer end of the shaft, and the downward pull of this belt, as at *d*, is such that the shaft is drawn down and a little out of line. This can be seen by examining

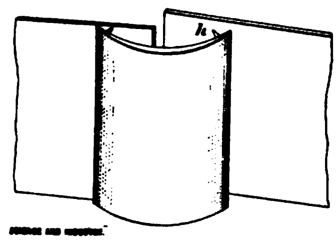


FIG. 10

the dotted straight line *e* to *e*. The result is that the outer end of the shaft is caused to grind in the bushings of the hanger and we get a hotbox, or at least a warm one, which gives trouble. The only remedy is to provide a hanger to support the outer end of the shaft. That is, there should be a support on each side of the pulley carrying the belt.

We frequently observe belts operating in shops and other places in which the conditions of running are similar to those presented in Fig. 8. Here the pulley is shown with the belt running upon it at one side. Perhaps the shafts are not correctly lined, and a high or low side is made on the wheels, to draw the belt from the central course.

Or, perhaps, the line of rotation made on the pulleys by improper setting causes this. Or the belt may be incorrectly laced, or it may be a little longer on one side than the other, due to the stretching of the leather, or other minor factors may combine to cause the trouble shown. The belt soon develops the torn and worn condition indicated at *f*, and is soon rendered useless and has to be replaced with a new one.

It is odd what mistakes really good workmen sometimes make in shafting and shafting devices. In Fig. 9 is a sample of one of the methods I saw used by a machinist for oiling a revolving wheel hub. He bored a hole through the flange of the hub, to the bearing, and in this hub inserted the oil cup *g*. Of course the centrifugal force of the revolving hub caused the contents of the oil cup to always be at the outer end, and no oil at all ever found its way to the shaft. The result was the heating and burning of the bearing, and then the workman saw his error.

We have fastening devices of many descriptions in use in the modern manufacturing establishment, among which are the metal clamps. These clamps are suitable if correctly applied. I have seen them put on in all sorts of shiftless ways. A careless way is illustrated in Fig. 10. Here the ends of the leather were evidently brought together in haphazard fashion and the metal points of the clamp driven home without regard to correctness of setting. Thus we have the irregularity at *h*. Such a union cannot hold long. The ends of the belt should be squared and the points of the clamps driven in only when it is assured that the clamp is perfectly set in relation with the butts. It may then be driven home and the points clinched.

THE HEAT BALANCE

R. T. STROHM

IN ANY case whatsoever, the efficiency of an apparatus is a ratio. Generally it is a ratio of input to output, as in the example of the steam engine, the dynamo, or the steam boiler. It is the utilization of heat in the last named of these that is concerned in this article.

The steam boiler is a means for the transformation of energy, just as are most engines, using the latter term in its broadest sense. It transforms the latent energy of the coal into the heat energy of the steam, thus putting this energy into a form whereby it may be utilized and turned to account through the medium of the steam engine or the steam turbine.

In the steam boiler there is a double transformation. The first takes place in the furnace and consists of the combustion of the coal. Here the carbon and hydrogen and other combustible elements of the fuel combine with the free oxygen of the air and by their union liberate heat. This heat, passing through the conducting materials of which the boiler is composed, changes the water from a liquid to a gaseous state, thus performing the second of the two transformations referred to.

The main combustible elements in coal are carbon and hydrogen. Besides these there may be a slight amount of sulphur, but usually its percentage is so comparatively small as to be negligible. There is also a varying amount of oxygen, nitrogen, and ash, according to the nature of the coal. In determining the heating value of a coal, however, it is common to consider only the percentages of

carbon, hydrogen, and oxygen which it contains.

A pound of pure carbon, completely burned to carbon dioxide, will give out by its combustion approximately 14,600 heat units. A pound of hydrogen when burned to form water, gives out approximately 62,000 heat units. From this data a formula has been deduced, by which, knowing the chemical composition of any given fuel, its theoretical heating value may be calculated. This formula is

$$\text{Heat} = 14{,}600\ C + 62{,}000\left(H - \frac{O}{8}\right)$$

in which C, H, and O represent the percentages of carbon, hydrogen, and oxygen, respectively, in a given sample of coal, as determined by chemical analysis. The heat thus found should be the same as that found by the aid of the coal calorimeter, but usually the latter is from 6 to 10 per cent. less than the former.

Let us take, for example, a Pennsylvania bituminous coal of the following composition: carbon, 76 per cent.; hydrogen, 6 per cent.; oxygen, 12 per cent.; nitrogen, 1 per cent.; ash, 5 per cent. Its total heat of combustion would be, by the formula,

$$\text{Heat} = 14{,}600 \times .76 + 62{,}000\left(.06 - \frac{.12}{8}\right)$$

$$= 11{,}096 + 2{,}790 = 13{,}886 \text{ B.T.U.}$$

It will be seen that in the second term of the equation given above we do not multiply the total percentage of hydrogen by its heating value per pound, but that we first substract $\frac{1}{8}$ of the percentage of oxygen. The reason for this lies in the fact that the oxygen in the fuel combines with $\frac{1}{8}$ its weight of hydrogen and so renders this much of the hydrogen unavailable for combustion, so that we have only the remainder, or $H - \frac{O}{8}$ to consider.

By such a method as this it is possible to find the heating value of any kind of fuel. And this should serve as a guide as to what may be expected of it when fed to the furnace of the boiler, though the probable variation of some parts, in quality, from that of the sample analyzed, may bring a different result.

In most cases where it is desired to find the efficiency of a boiler, a test of several hours' duration is made, in which the fuel supplied and the water evaporated are carefully noted, together with the various pressures, temperatures, and corrections. From these the ratio of the heat utilized in evaporating the water to that supplied to the boiler furnace is obtained, and is taken as a measure of the efficiency. It is interesting to go a step further than this, however, and to consider in detail the distribution of the heat supplied. This necessitates what is known as a heat balance.

This heat balance is actually a sort of account. On the debit side is placed the heat which is supplied to the boiler, and on the credit side the heat which is given out from the boiler furnace. To form a perfect balance, the heat units should sum up the same on both sides of the account.

Heat is supplied to the boiler in three separate ways. First, and principally, there is the heat which is due to the combustion of the fuel; second, the air necessary to support this combustion carries with it a certain amount of heat; third, the feedwater brings heat to the boiler, which must be taken into account. These three constitute the sources of heat.

Heat is given out in a far greater number of ways. Most of it goes to evaporate the water to form dry steam. But since steam is rarely perfectly dry as formed by the ordinary steam boiler, there is a certain amount of heat in the moisture which is suspended in the steam.

The dry flue gases carry away a very large amount of the heat generated by combustion, especially where natural draft is used and the force of the draft is dependent upon the temperature of the flue gases. There is also moisture in these gases, due to three causes. First, moisture in the coal itself; second, water formed by the combustion of hydrogen in the fuel; third, the water vapor contained in the air which is admitted to support combustion.

There is still another loss in the flue gases which has not been touched upon. It is the formation of carbonic oxide. In other words, it is the result of incomplete combustion, in which the carbon of the fuel is given only half the supply of oxygen with which it would naturally combine. The loss due to an insufficient supply of oxygen will become apparent when it is stated that a pound of carbon burned to carbon monoxide will give out only 4,400 heat units as compared with the 14,600 heat units obtained when the same amount of carbon is burned to carbon dioxide.

This loss is not actually a loss of heat, since the heat has not yet been generated. But since the fuel is the main source of heat, any process by which a portion of that fuel is thrown away without being utilized to its fullest extent is wasteful, and must be considered as a heat loss, since the unburned carbon still possesses calorific possibilities.

Then there is present in every steam-generating apparatus, no matter how well designed or how carefully protected, the radiation loss. This is a continual waste and should be reduced to a minimum by the use of refractory settings and nonconducting coverings for the boiler shell wherever possible. Finally, there is a small loss due to the removal of ashes and clinker when the fire is cleaned or the ashpit cleared. If some of the finest parts of the coal fall through the grates, as is the case to a greater or less extent in all boilers, this also becomes a heat loss.

For an example let us take a fuel having the following composition: carbon, 79 per cent.; oxygen, 10 per cent.; hydrogen, 4 per cent.; ash, etc., 7 per cent. Its theoretical heating value is, then,

$$14{,}600 \times .79 + 62{,}000\left(.04 - \frac{.10}{8}\right)$$

$= 13{,}239$ heat units per pound.

It is necessary now to find the amount of air required to burn a pound of fuel. To convert a pound of carbon to carbon dioxide requires 11.6 pounds of air, and to burn 1 pound of hydrogen completely requires 34.8 pounds of air. When the fuel itself contains a certain percentage of oxygen, this oxygen unites with one-eighth its weight of hydrogen. Consequently, the weight of air, in pounds, necessary to burn 1 pound of a given fuel may be found from the formula

$$W = 11.6\,C + 34.8\left(H - \frac{O}{8}\right),$$

in which W is the weight of air in pounds, and C, H, and O the percentages of carbon, hydrogen, and oxygen, respectively, contained in the fuel.

Assume the air supply to be at a temperature of 70° F. The minimum weight of air required is, then,

$$W = 11.6 \times .79 + 34.8\left(.04 - \frac{.10}{8}\right)$$

$= 10.121$ pounds per pound of fuel. The air required for the burning of this fuel, being at a temperature of 70°, is 38° above 32°, which is the point from which we shall reckon the heat. The specific heat of atmospheric air is .2375. So that each pound of air admitted to the furnace brings in $38 \times .2375 = 9.025$ heat units, and 10.121 pounds bring in $10.121 \times 9.025 = 91.342$ units.

But it is seldom that this air will be sufficient to cause complete combustion, and it is quite common to admit twice the theoretical amount of air required. This means, then, an addition of $2 \times 91.342 = 183$ heat units supplied in the air.

Let us take the feedwater at a temperature of 180°, and the equivalent evaporation at 9 pounds of water per pound of coal. This would mean an actual evaporation of 8.411 pounds, assuming the boiler to carry 90 pounds of steam, by gauge. Then the heat brought in by the feedwater is $(180 - 32) \times 8.411 = 1{,}245$ heat units. So that the total heat supplied to the boiler per pound of coal burned is $13{,}239 + 183 + 1{,}245 = 14{,}667$ heat units. This is the total on the debit side of our account.

Now turn to the credit side, in which we consider the various ways in which the heat is distributed. Assume that the steam formed is 97.5 per cent. dry. The evaporation per pound of fuel is 8.411 pounds of water. Then 97.5 per cent. of this, or 8.2 pounds, is dry steam at 90 pounds gauge pressure, and the remainder, .211 pounds, is water suspended in the steam at the temperature corresponding to a pressure of 90 pounds. The total heat above 32° in one pound of steam at 90 pounds pressure is 1,182.88 heat units, so that in 8.2 pounds of dry steam there are 9,699.6 heat units. At this pressure the temperature of the steam is 330.956° F., so that each pound of moisture in the steam contains $330.956 - 32 = 298.956$ heat units. Then .211 pounds of moisture must contain $.211 \times 298.956 = 63.08$ heat units. The evaporation per pound of coal, then, takes up $9{,}699.6 + 63.08 = 9{,}763$ heat units, nearly.

Suppose that the flue gases leave the boiler at a temperature of 532° F. In order to find the amount of heat which they carry away we must know the composition of the flue gases. This may be done by calculating the products of combustion of one pound of the fuel which we have assumed, though in practice an actual analysis of samples of the flue gases would be made.

The amount of free hydrogen in the fuel is

$$H - \frac{O}{8} = .04 - \frac{.10}{8} = .04 - .0125$$

$= .0275$. So that we have for the fuel, carbon, .79; hydrogen, .0275; water, $.10 + .04 - .0275 = .1125$.

Now, 1 pound of carbon requires $2\frac{2}{3}$ pounds of oxygen for complete combustion, the result being $3\frac{2}{3}$ pounds of carbon dioxide. So .79 pounds of carbon will result in $.79 \times 3\frac{2}{3} = 2.90$ pounds of carbon dioxide. One pound of hydrogen requires 8 pounds of oxygen for complete combustion, the result being 9 pounds of water. So we have for the water in the flue gases $.1125 + (.0275 \times 9) = .36$ pounds. The nitrogen was, of course, unconsumed, and as it forms 77 per cent. of ordinary atmospheric air, there will be $.77 \times 10.121 = 7.79$ pounds of nitrogen in the flue gases. And finally there will be the 10.121 pounds of free air which was supplied in excess to insure complete combustion. The flue gases from the burning of 1 pound of fuel consist, then, of the following:

	Pounds
Carbon dioxide	2.90
Water (as steam)	.36
Nitrogen	7.79
Free air	10.121

The specific heat of carbon dioxide is .217; of steam, .48; of nitrogen, .2438; and of air, .2375. The dry portion of the flue gases consists of the carbon dioxide, the nitrogen, and the free air. The heat carried out by these gases can be calculated by multiplying together with the specific heat, the

weight, and the temperature above 32°, of each. Thus,

		Heat Units
Carbon-dioxide ...	$2.90 \times .217 \times (532-32) =$	314.6
Nitrogen	$7.79 \times .2438 \times (532-32) =$	949.6
Free air	$10.121 \times .2375 \times (532-32) =$	1201.8
		2466.0

The heat carried away by the water in the shape of superheated steam is $.36 \times .48\ (532-32) = 86$ heat units. Or in all, the flue gases carry away $2466 + 86 = 2552$ heat units for every pound of fuel burned.

We are now ready to strike a balance in our heat account, and to determine the losses unaccounted for. On the debit side we have 14,667 heat units supplied. On the credit side we have $9,763 + 2,552 = 12,315$ heat units. There is remaining a difference of $14,667 - 12,315 = 2,352$ heat units for which we have not accounted in any way.

It must be remembered, though, that we did not consider the losses due to radiation and to the heat in the ashes and cinders. The sum of these losses may range from 4 to 24 per cent. of the total heat supplied, according to the condition of the boiler and its design. The heat which we have not accounted for is but 16 per cent. of that supplied, and may safely be considered to represent the losses due to radiation and other causes.

THE MODERN STEAM ENGINE

THE advances made in steam engineering in recent years have brought changes to this industry, which today is rapidly passing out of the experimental stage. As the source of power for electrical stations, the steam engine will probably be employed even when electricity has monopolized many fields which have been heretofore reserved for steam alone. The steam engine has made almost as rapid and revolutionary changes as the different forms of electric dynamos. In many lines of manufacturing and power production the steam turbine has come to be the new type of engine which supercedes all others. The application of this to the ocean steamers first demonstrated its peculiar fitness for certain lines of work. Within the current year remarkable advances have been made in installing ocean steamships and naval ships with the steam turbine, and engineers have come to recognize this type of engine as marking a new era in this field.

Even in marine engineering, however, the turbine engine has its limitations as well as its particular good points. In such steamers where frequent stopping and starting are required, the turbine engine will never prove of great value. There is considerable loss in reversing the engine quickly. For this reason it is not considered the best type for small war vessels that must be handled in short turning space and depend for their success largely upon rapid maneuvering power. There has been an effort to overcome this difficulty of slow reversing by having separate reversing motors, but it is not likely for the present at least that this will entirely overcome the undesirable features of the engine. Where steady speed is required the turbine engines on the ocean steamers have no equal, and they are destined to replace all others.

The equipping of the new powerful ocean steamers with the turbine engines has been going on for some time, and nearly all the new steamers that are expected to attain a high speed are being built with similar power engines. Lately there has been a disposition to fit the larger pleasure yachts with

the same class of engines. The small steam yachts may never be thus equipped, but since the recent successes and improvements with the turbine engines on the water have been made the builders of yachts of the first-class are ordering the new type of engine. Both in Great Britain and in this country the marine builders are adopting and advising these engines for nearly all craft intended for ocean navigation. The widespread appreciation of this fact, and the general acceptance of the superiority of the turbine engine for marine purposes, promises revolutionary effects in ocean navigation of the near future. Greater speed and efficiency combined with greater economy of operation, will tend to be the result of this change, and these are the points after which modern engineering is striving.

The turbine engine on the land, both for stationary and railroad purposes, has likewise made remarkable advances within a few months. The successes attained on the high seas with the new type were bound to be tested sooner or later on the land. There is one field in particular where the turbine engine will prove of the greatest importance, and that is, for manufacturing purposes in connection with generating electricity for commercial purposes. Manufacturers in all parts of the country have been closely watching the developments and experiments made with the new engines, and they have reached the point in many cases where they are ready to adopt this form of power. Probably the largest turbine engine in this country is located at Hartford, Connecticut, where it is employed in generating electricity for power and light. Not only this, but it is claimed to be the most economical steam engine in the world. The General Electric Company have a 750-horsepower turbine in operation at their works, and it is said to give the best satisfaction of any operated by them. The Hartford turbine, which has been in operation for about a year, developes 2,500-horsepower. In this country the turbines are turned out both for home and export use, and considerable numbers are now in the process of manufacture for shipment to the South African gold mines, where they are to be used in generating electricity. Although the Parsons' turbine is an English patent and invention, the American company holding the rights in this country have succeeded in making further improvements upon the engines and in manufacturing them at smaller cost than those in England. There has, consequently, grown up quite an important manufacturing industry in this particular line.

It is only natural that English manufacturers and marine engineers should take up the new type of engine more generally than those in this country. It is not surprising to learn, therefore, that the London underground railways are preparing to equip their plant with ten 10,000-horsepower turbines for driving the enormous electrical generators. Over there they have reached the point where they consider the steam turbine no longer an experiment, and its adoption for railway power is something that brings a new factor into view. It was not supposed a few years ago that the turbine engine would ever enter the field of railroad operation, but with its adoption for driving electrical generators a new phase of the question is presented. It has already brought matters to something like a standstill in equipping the New York Rapid Transit tunnel with generators and steam engines. Only six engines of the reciprocating type had been ordered when definite announcements were made that the London underground

railways were to be equipped with turbine engines. Now, the engineers in control of the New York tunnel will wait to see further the results of experiments with the new engines. It is the expectation of those interested in the subject that eventually the tunnel will be equipped entirely with the turbine engines, but owing to the limited power given to those constructing the new rapid transit tunnel in New York, it would be impossible to equip the plant with anything that has an experimental suggestion to it. In the field of electric traction it must be said that the turbine engine has not yet technically passed out of the experimental field. In spite of this, however, the leading engineers believe that it is only a matter of a few years when the turbine engines will take the place of the old reciprocating type in nearly all marine craft, stationary plants of large size for driving electric generators, and for different manufacturing purposes of a somewhat similar nature.

ELEMENTARY PRINCIPLES OF ELECTROMAGNETS—I

IN this article it is the writer's intention to explain merely the principles of the magnetic circuit and the winding of coils upon which the design of electromagnets depends, and not to enter further upon the latter subject.

The reader is doubtless familiar with the fact that if a current flows through a coil of wire called a solenoid, that there is produced inside and around the coil what is called a magnetic field. It is customary to represent this magnetic field by what are called lines of force. No such lines actually exist, but by means of them the principles of the magnetic circuit may be more readily understood. A solenoid through which there is flowing a current and the resulting lines of force that represent the magnetic field is shown in Fig. 1. Each line of force represents the direction in which an imaginary free pole would move if placed upon it and not opposed by any other force.

Every line of force must form a complete circuit. Although a line may apparently leave the end of the solenoid and disappear in space, it must eventually return to the opposite end of the solenoid, however far it may go out into the surrounding space. Practically the same conditions exist, excepting the intensity of the field, as in an ordinary permanent bar magnet; that is, the lines of force pass out from the north end, enter the south end, and pass through the interior of the solenoid. One end of the solenoid acts the same as the north pole of a bar magnet and the other end as the south pole. The direction of the lines of force through the solenoid, and hence its polarity, depends upon the direction in which the current circulates around the air core. If the direction of the current is known, the polarity of the solenoid may be determined in the following manner: In looking at the end of the helix, if the current flows around it in the direction of the hands of a watch, the near end will be a south pole and the other end a north pole; if the current flows in the other direction, the polarity will be reversed. This is a good rule to remember when there are several coils to be placed on a magnet having more than one pole. This rule is clearly illustrated by Fig. 2.

Now, the number of lines of force passing through each unit area inside the solenoid represents the intensity of

the field, or the magnetizing force, as it is also called. This quantity, that is, the number of lines per square centimeter is usually represented by the letter H. Then 6.45 H will be the

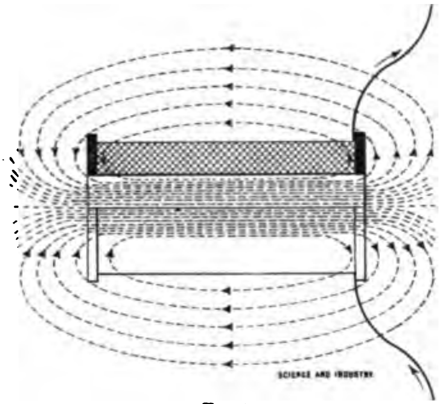


FIG. 1

number per square inch. At the International Convention of Electrical Engineers at Paris, in 1900, the *gauss* was adopted as the name for the unit of magnetic field strength, or field density, as it may also be called. C. F. Gauss, after whom the unit is named, introduced the absolute, or centimeter-gram-second, system of units, and he is also well known for his method of simultaneously determining the strength of the horizontal component of the earth's magnetism and the magnetic moment of a permanent bar magnet. Hence, 5 gausses means 5 lines of force per square centimeter, or $5 \times 6.45 = 32.25$ lines per square inch.

If H represents the number of lines of force in air per unit area inside the solenoid, then evidently the total number of lines of force threading through the solenoid is equal to H multiplied by the area of the inside of the solenoid. This represents what is called the total flux inside a solenoid *provided there is no iron*, or other magnetic material, inside or around the solenoid. If there is any magnetic material inside or near the solenoid, the flux would be very much greater, as will be shown presently.

The same convention referred to above, also adopted the maxwell as the name for the unit of magnetic flux. That is, five lines of force may now be called five maxwells. We can say a flux density is 5,000 gausses when we mean 5,000 lines of force per square centimeter, but when the flux density is 5,000 lines of force per square inch we cannot use gausses but must say 5,000 maxwells per square inch.

MAGNETIC PERMEABILITY.

If there is a magnetic field in air produced by a solenoid, a permanent magnet, or otherwise, there are a certain number H of lines of force threading through each unit area. In a uniform field, in air or other nonmagnetic substance, H is the number of lines of force per unit area; in a nonuniform field, H may be considered as the average number of lines of force per unit area.

Now, if a magnetic substance, such as soft iron, is placed in this magnetic field, it is a well-known fact that the magnetism in the iron is much more intense than it was in the same space before the iron was introduced; that is, there are a great many more lines of force per unit area in the iron than in the same space before the iron was introduced. The facility afforded by any

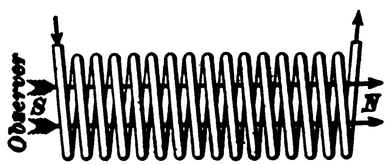


FIG. 2

substance to the passage through it of lines of force is called its *magnetic permeability*, or, simply, its *permeability*. Now, the permeability of air is taken as 1, and since that of soft iron may be

2,000 times as great, it follows that if a piece of soft iron be placed inside a solenoid through which a current is flowing, the number of lines of force will be greatly increased, and the iron will be much more highly magnetized than the air which it displaced. A magnetic substance, therefore, offers a better path for the lines of force than air or other nonmagnetic substance.

If we denote by H the field density, that is, the number of lines of force per unit area in the air space before the iron was introduced, and by B the density in the iron after it is placed in the same space where the field density was previously H, then the ratio between B and H, that is, $\frac{B}{H}$, is called the *magnetic permeability* of the iron. Hence, if we denote the permeability by the Greek letter μ (pronounced *mu*) which is customarily used for this purpose, we have the formula

$$\mu = \frac{B}{H}. \qquad (1)$$

By the aid of certain electrical instruments the magnetic density in iron can be determined.

The conductivity of a conductor, if the temperature remains constant, does not depend upon the strength of the current flowing through it, but the permeability μ of a magnetic substance *does depend upon the degree to which it is magnetized*, as will be shown presently; that is, $\frac{B}{H}$ has not the same value for different degrees of magnetization even in the same piece of iron. In order to calculate μ we must know the value of the magnetic density B produced in the iron by each particular magnetizing force H, because the permeability has a different value for every value of H, increasing up to a certain limit as the magnetizing force increases. In all kinds of magnetic substances, the permeability decreases when the magnetism is increased beyond the limit just mentioned. This tendency of the substance to become less permeable is called *magnetic saturation;* that is, the substance becomes saturated with magnetism. A limit is never reached where perfect saturation is produced, but there is a limit beyond which it becomes impractical to magnetize the substance. The practical saturation point in wrought iron and cast steel is between a density of 120,000 and 130,000 lines of force per square inch. In gray cast

DATA FOR B-H CURVES

H		Ampere Turns Per Cent. Length	Ampere Turns Per Inch Length	Cast Iron		Cast Steel		Wrought Iron		Sheet Metal	
Per Sq. In.	Per Sq. Cm.			B Gausses	Maxwells Per Sq. In.	B Gausses	Maxwells Per Sq. In.	B Gausses	Maxwells Per Sq. In.	B Gausses	Maxwells Per Sq. In.
64.5	10	7.95	20.2	4,300	27,700	11,500	74,200	13,000	83 800	14,300	92,200
129.0	20	15.90	40.4	5,700	36,800	13,800	89,000	14,700	94,800	15,600	100,700
193.5	30	23.85	60.6	6,500	41,900	14,900	96,100	15,300	98,600	16,200	104,500
258.1	40	31.80	80.8	7,100	45,800	15,500	100,000	15.700	101,200	16,600	107,100
322.6	50	39.75	101.0	7,600	49,000	16,000	103,200	16,000	103,200	16,900	109,000
387.1	60	47.70	121.2	8,000	51,600	16,500	106,500	16,300	105,200	17,300	111,600
451.6	70	55.65	141.4	8,400	59,200	16,900	109,000	16,500	106,500	17,500	112,900
516.1	80	63.65	161.6	8,700	56,100	17,200	111,000	16,700	107,800	17,700	114,100
580.6	90	71.60	181.8	9,000	58,000	17.400	112,200	16,900	109,000	18,000	116,100
645.2	100	79.50	202.0	9,400	60,600	17,700	114,100	17,200	110,900	18,200	117,300
967.5	150	119.25	303.0	10,600	68,300	18,500	119,200	18.000	116,100	19,000	122,700
1290.0	200	159.0	404.0	11,700	75,500	19,200	123,900	18,700	120,800	19,600	126,500
1613.0	250	198.8	505.0	12,400	80,000	19,700	127,100	19,200	123,000	20,200	130,200
1935.0	300	238.5	606.0	13,200	85,100	20,100	129,600	19,700	127,000	20,700	133,500

H = 1.258 ampere turns per cm. = .495 ampere turns per inch.

iron the practical saturation point is between 70,000 and 85,000 lines of force per square inch.

In order to design an electromagnet, it is necessary to first know the magnetic properties of the particular quality of iron to be used. By means of tests made upon small samples of the iron, the values of B, H, and μ, may be determined. Such tests require a large number of careful measurements, and hence it is customary to use results made in some laboratory or by a large company on an average quality of iron and steel. The results given in the accompanying table, for which credit is due to Foster's Electrical Engineer's Pocketbook, are average values for the best quality of iron and steel manufactured in the United States.

Since no two pieces of the same kind of iron or other magnetic substance, even from the same factory, are likely to have exactly the same magnetic qualities, it is impossible to give a table of values or a curve that will apply to every piece of wrought iron, or one that will apply to every piece of cast iron, or to steel; in fact, the magnetic qualities vary so much even in different pieces of the same metal that each sample should be separately tested and its qualities determined for very exact work; but tables, giving the values of the magnetic properties of an average piece of wrought iron, cast iron, and mild steel are generally exact enough for most calculations made in designing electromagnets.

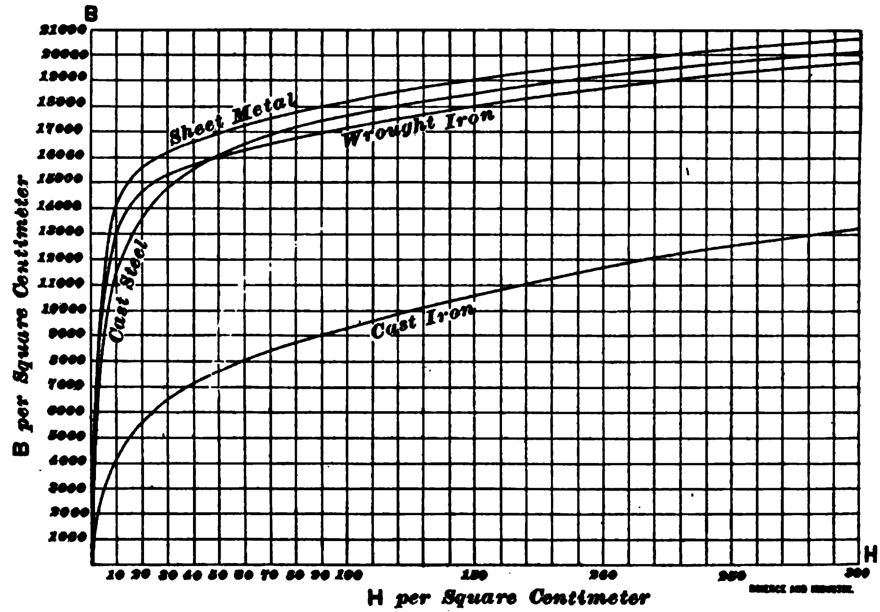


FIG. 8, (a)

CURVES OF MAGNETIZATION.

The most convenient mode of representing the magnetic qualities of iron is to plot on a sheet of cross-section paper a magnetization curve that will indicate the relation of the magnetizing force H to the magnetic density B. Where two related quantities, such as B and H, do not vary proportionately, a curve is necessary in order to determine intermediate values as well as to show the manner in which the relative values change. For instance, a curve

showing the relation between B and H must be plotted from the values given in the above table in order to determine the value of B for $H = 175$, because the value of B exactly corresponding to this value of H was not measured. By means of a curve, however, the value of B can be determined quite accurately. The curve given in Fig. 3 (a) was made by plotting the flux density in lines per square centimeter corresponding to the field density in lines per square centimeter as given in the table. Fig 3 (b) was made by plotting the flux density in lines per square inch, that is, maxwells per square inch as given in Table I, corresponding to the field density in lines per square inch; the latter being 6.45 times the value given for H in the table.

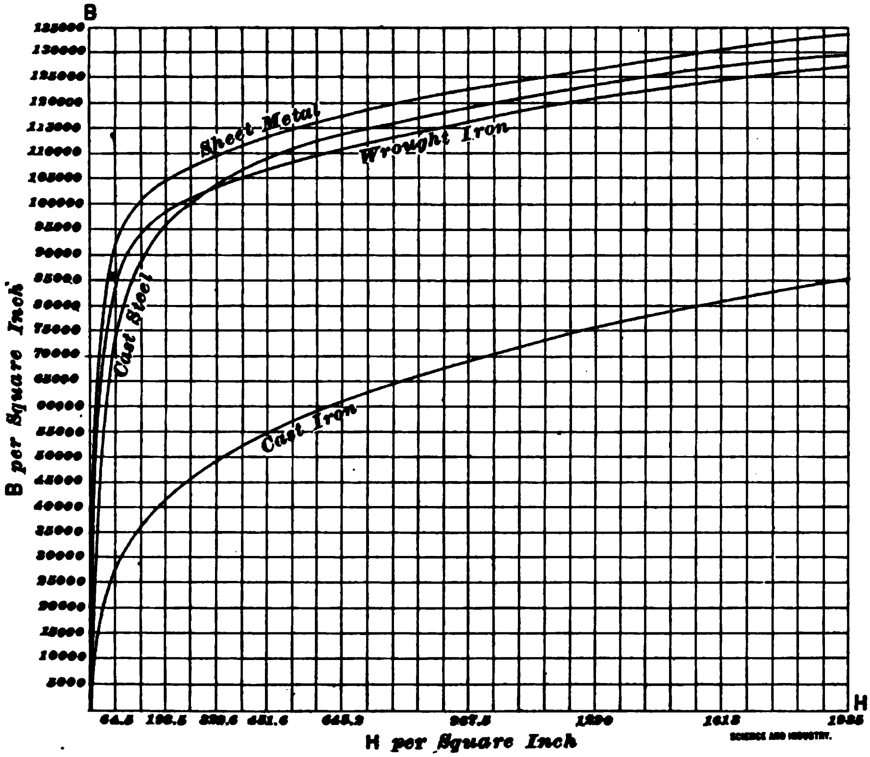


FIG. 3 (b)

ALUMINUM NAILS

After many numerous experiments and trials, an alloy of aluminum has been made, with which nails, staples, and tacks can be made to compete with copper. Among other advantages claimed for the new material, is, that it is not affected by the weather, and will not deteriorate. It is to be noticed that this quality should recommend the nails for use in laying roofs, lining tanks, etc., and also that, as the alloy is non-corrosive and non-poisonous, the new nails ought to find favor among makers of refrigerators. When the difference in point of number and weight is taken into consideration, it is seen that aluminum nails are about 4 cents a pound cheaper than copper nails.

ELECTRICITY ON STEAMERS

GEORGE E. WALSH

THE electrical field has been greatly broadened in recent years by the use of electricity for power, lighting, and other purposes on shipboard, and the development of the work has been remarkable within the past year. One does not have to go so very far back to find ships of the most prominent lines without any electric plant aboard for even lighting purposes. It was only in 1880 that the first electric light plant was installed on shipboard in this country, and that was on the steamship *Columbia*, of the Oregon Railway and Navigation Company. But in the twenty years that have elapsed, electricity has not only made itself necessary for lighting purposes on every steamer of any size and importance, but it has become the necessary agent for innumerable other useful offices. The modern ocean steamer, war vessel, or coaster is electrically equipped in a way that makes one cautious about tampering with the internal mechanism until he knows his way about. Indeed, the intricate machinery of a modern steamer is so great and puzzling to an outsider that it presents nothing but confusion to his mind.

Electricity is used most generally on steamers for lighting purposes, and upward of 600 vessels in this country have been installed with electric light plants, representing an expenditure of something like two million dollars. These plants run all the way from the very small, simple affairs on the river boats to the large, complicated and costly installations on the big ocean liners and United States battleships and cruisers. So general has the use of electric lights become on shipboard that passengers expect them on all the vessels they sail by, and take it as a matter of course.

The use of search-lights on steamers is rapidly becoming almost as general. It was only a few years ago that the search-light was a great novelty, and people would travel some distance to see the war vessels use it for lighting up the water. It was in some way accepted as a sort of war adjunct, and adapted only to our cruisers, monitors, and battleships. Consequently only the war vessels were equipped with search-lights. But today this powerful electric light has become a necessary feature of inland navigation where rocks, reefs, and other obstructions in a narrow, tortuous river make night navigation uncertain. Many of the river and coasting vessels are equipped with search lights to enable them to pick their way through a bad channel at night. By adopting this means of lighting up their pathway steamers can enter harbors and rivers after dark which formerly had to anchor outside until daylight. The channel is made as clear and distinct by the search-light as it is in the day time by the sun. In the Potomac river in particular is the search-light of value in enabling the boats to travel at night; and also on the Mississippi, where obstructions are frequent and as changeable as the tides and winds. Nearly all of the first-class lake vessels are also being equipped with search-lights for this same reason.

The search-light was first used for signaling at sea or along the coast by the United States war vessels, as well as for picking up an enemy that might attemp to approach under cover of darkness. The use and value of this light for signaling are only faintly

appreciated today, but many of the coasting steamers and ocean greyhounds are being equipped with them for this purpose. By means of the search-lights, signals with the shore or between two passing vessels can be exchanged at a distance of fifteen to twenty miles. It is estimated that thousands of dollars will be saved to lake and river traffic by installing all the boats with such powerful signals. On the Great Lakes the passing steamers could in this way signal with almost any part of the coast and save useless trips into ports.

The search-light has also been found to be the best means of signaling in fogs, and the Long Island Sound steamers have adopted it as the best precaution against accident. The search-light is the only thing that has been found to penetrate a fog to any distance and the direction of it disclosed without possibility of error. Sound is notoriously uncertain and deceptive in fogs, and more than one collision has been caused by this fact. The rays of light from the search-light, however, do not deceive the eye. When thrown straight up into the air, and again on the surface of the water to make use of it as a reflector, the light betrays the location of the vessel through the densest fog. The Atlantic ocean steamers are also adopting the search-light as a fog precaution when crossing the Banks, and there is little doubt but it will prove of great value in averting accidents. In the near future the installation of an electric light plant on a steamer will include also a search-light, equipped for fog signaling and for night use in narrow rivers or when coasting along the shore.

On our large steamers and war vessels electric signals and telephone communication with different parts of the vessel are necessary parts of their equipment. The commanding officer is placed in immediate communication with every part of his vessel, and he can talk with his engineer in the boiler room below or the purser in his office. He no longer has to depend upon dumb signals, which in an emergency might convey the wrong message. He distinctly talks with his officers and crew, and can have his orders repeated through the telephone in the human voice to satisfy himself that they are understood. Thus dangers and mistakes can be avoided as never before. The controlling power of the mechanism on a man of war is largely electrical. The great guns are operated and fired by electricity, the conning towers are turned by the same power, the ammunition hoist is operated electrically, and the guns loaded by an ingenious electric device. A dozen and one things are operated and controlled by this same power, and the row of buttons in the navigating officer's room or on the bridge indicate a complex electrical equipment of the most efficient kind.

The field in which electricity is making new strides on ships is in the power department. Not that the steamers will be electrically propelled for a good many years to come, if ever, but they will have electric plants on board to operate minor machinery. Most of the auxiliary machinery will in time be operated by electric motors. There has been less advance in this direction on steamers than on shore. In the modern shop or manufactory, where many separate machines are required, electric motors invariably do the work. This is due to the saving in expense and labor. Most of this machinery is in operation only a part of the time, and the cost of keeping it in continuous operation by steam is great, while the electric motor does its

work only when needed, and costs nothing to stand idle for a few hours a day.

The same is true on steamers. Every time the steamer comes into port or leaves, there is work for the separate engines to do, and at sea a break in the machinery might suddenly cause trouble if the auxiliary machines could not be quickly put in operation. Some of the latest ocean steamers have a score or more of separate electric motors.

They are used for driving the blowers to the furnaces, for heating and ventilating cabins and boiler and engine rooms, for operating refrigerating compressors, for hoisting and loading and unloading freight, ashes, and provisions, and for telephones and signal lights. The ill-fated *Bremen* had its sixteen deck cranes operated by thirty-two motors, all controlled by one handle, and they worked so well that freight could be loaded and unloaded much quicker than by the old donkey engines, with their squeaking and cranky winches. The capacity of these cranes was several times that of any old-fashioned winch.

The use of electrically operated cranes on shipboard is bound to be more generally appreciated, and within a few years every freight steamer of note will have to adopt them to hold her own in competition with those thus modernly equipped for handling freight quickly and inexpensively. By means of the cranes, cargoes can be loaded and unloaded practically without any noise, for the gigantic lifting apparatus is as noiseless as it is efficient. These are only a few of the many directions in which electricity undoubtedly will, in the near future, find ample room for development in marine architecture.

ELECTRIC PLANT OPERATED BY WATER POWER

J. L. DICKSON

THE plant herein described is on a farm situated in the southern part of Pennsylvania. There is a small creek with a swift current running through the premises, from which a tail race is run, and over this is erected a building for the machinery. A water turbine is attached to a vertical shaft, and to this shaft is belted a small 40-light dynamo, by means of a counter-shaft and pulley.

This dynamo has an E. M. F. of 110 volts, and the armature revolves at a speed of 1,800 revolutions per minute; the current from this machine is divided into three circuits, one running to the private residence, lighting about 25 lights and operating a small motor in the kitchen for grinding coffee, meat, etc.; the second circuit runs to the tenants' house and to the barn, lighting about 15 lamps and operating several small motors in the barn for grinding feed, chopping and shelling corn, etc.; the third circuit connects with the butter house, where it operates several lights and a small motor used to separate milk and churn butter.

It must be understood that this small dynamo does not operate all of these circuits at one time, in fact, it operates only one of them at a time, but as that is all that is necessary, the arrangement is perfectly satisfactory. A line is also run to a near-by grove, used for picnics, etc., requiring the occasional use of an arc light.

The cost of operation of the entire plant is practically nothing, as the

dynamo only requires to be started and stopped, and the water power is, of course, free; so, considering the service furnished, the plant is very economical.

THE JUNE SUPPLEMENT

Our June supplement consists of some miscellaneous tables and formulas, which will be found useful to both the machinist and draftsman. They have been made up from the results of actual practice, and will be found thoroughly reliable.

MEETING OF THE A. S. M. E.

The forty-fifth meeting of the American Society of Mechanical Engineers was held at Boston, Mass., May 27th to 30th inst. The meeting was informally opened on Tuesday evening in Huntington Hall, and on Wednesday morning the business session commenced, followed by the reading of papers, which covered a wide range of topics. The subjects were presented in an able manner. The committee appointed to standardize a system of testing steam engines made their final report. The report is very complete and goes into every detail of the subject.

There was a large number of members present, and the meeting was voted a complete success on every hand.

LOCAL ACTION IN PRIMARY BATTERIES

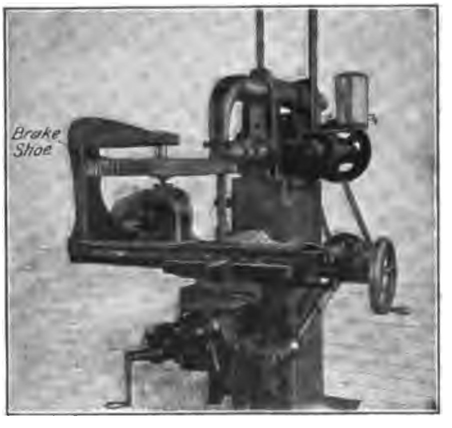
Commercial zinc is not chemically pure, but contains impurities, such as bits of iron, carbon, or other substances. When the zinc is immersed in any liquid which attacks the zinc more than the impurities, an electromotive force is set up; and since the two substances are connected through the metal, local currents are generated which eat away the zinc until the foreign substance is set free and falls away. This is called local action. When the zinc is amalgamated, that is, coated or alloyed with mercury, the mercury seems to cover up the impurities and to bring only the pure zinc to the surface. Moreover, the smooth surface seems to hold a film of hydrogen, when the cell is not at work, that protects the zinc from attack by the acid and prevents local action at all times.

CUTTING A LARGE GEAR ON A SMALL MILLING MACHINE

W. L. Bean

The gear-wheel shown in the accompanying illustration has a diametral pitch of 4 inches, a pitch diameter of 20 inches, and therefore 80 teeth. The face is two inches wide.

The cast-iron knee or angle is bolted to the table of the machine, and the gear is placed on a mandrel turned to fit the tapered socket of the inverted



index head, the mandrel having a bearing in the casting. A brake shoe held by two set screws is placed diametrically opposite the cutter and holds the gear firmly in place, though of course it must be loosened for each setting. A jack supports the gear under the cutter.

This method has given perfect satisfaction, and the knowledge of it may be of some advantage to others.

BOOK NOTICES, CATALOGUES, AND TRADE NOTES

Lessons in Practical Electricity, by C. Walton Swoope. Published by D. Van Nostrand Co. Price $2.00.

This work is intended as a textbook for students beginning the study of electricity, and commences by treating the elementary principles of the subject. No knowledge of mathematics or general science is assumed, and the book can well be used for private study. The subject is treated from a practical standpoint and many valuable examples occurring in actual practice are given. Illustrations are freely used and greatly aid in making the theories advanced easy of comprehension. The style throughout is clear and forceful, and it is very evident that the author was a man thoroughly acquainted with the subject and admirably equipped to express himself. The book is well worth reading by any one at all interested in the subject.

The Practical Gas Engineer, by E. W. Longanecker, M. D.

This book is eminently practical, as its title indicates, and is intended both for the operating gas engineer and the prospective gas-engine purchaser. The author is evidently a man who has had much experience in the actual handling of gas engines, and in this book he gives the results of his experience in a clear and concise manner. The whole subject is covered, commencing with an explanation of the different cycles and going on to the installation of the completed engine. The book is of handy pocket size and will unquestionably be found of value to those interested in the subject.

Marshall's Logarithmic Tables, by Thos. W. Marshall. Published by the Engineering News Publishing Co., New York.

This little book consists of logarithmic tables of measures of length from 0 to 50 feet at intervals of $\frac{1}{16}$ inch. A few examples are given at the beginning of the book, illustrating the method of using the tables. The book is well printed on good paper, bound with flexible leather covers, and is of convenient size for the pocket. It will undoubtedly prove a handy book of reference for many engineers.

Plaster Casts and How They Are Made, by Frank Forest Frederick, Professor of Art and Design in the University of Illinois. Published by William T. Comstock, New York. Price $1.50.

The preface of the book states that it is a plea for the more general appreciation of the artistic qualities and use of plaster of Paris casts, and a brief historical review of the art of casting from the time of the Greeks to the present. Directions are given for making casts by the waste, piece, elastic, and sulphur model processes, casting from life, oiling, painting, cleaning, and mending and packing the casts, and notes upon clay modeling. Numerous illustrations are used to elucidate the text, which is full of useful information and practical hints for the modeler and the molder. To those interested in clay modeling and plaster casting, we can unhesitatingly recommend this book.

We are in receipt of a circular of the Eureka Mfg. & Supply Co., St. Paul, Minn., manufacturers of the Eureka bicycle-motor castings. This company supplies castings to those of a mechanical turn of mind who wish to do part of the work on their motors themselves.

We have received Catalogue No. 19 of the Penberthy Injector Co., Detroit, Mich., for 1902. The catalogue is of standard size, well gotten up, and gives full particulars concerning their product.

North Bros. Mfg. Co., Philadelphia, Pa., have issued their 1902 catalogue describing the hardware specialties manufactured by them.

In the July, 1901, number of Science and Industry, in the article on "Telephone Extension Bells for Power Houses" was illustrated and described an extension-bell circuit-closer made by the Garton-Daniels Company. Since then this company has designed and is manufacturing an improved model of the same device. From the sample, which we have received, we notice that the new model circuit-closer, although exactly the same in principle, has a better adjustment, is smaller, and at the same time its construction is stronger, so that it cannot get out of order very easily. It is sold cheaper than the former model.

The Safety Explosive Co., of New York, has been succeeded by the Masurite Explosive Co., of the same city, manufacturers of the new explosive, masurite. Mr. Fred. L. M. Masury is president of the new concern.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

MECHANICAL

(153) How many feet would a steam siphon lift water, if operated by 40 pounds air pressure instead of 80 pounds steam pressure? C. K., Baltimore, Md.

ANS.—The terms "lifting" and "non-lifting" when applied to steam siphons and injectors usually refer to their capacity to raise water to their own level. The limit for the length of the suction pipe with either air or steam is the height water will rise in a vacuum. This limit is 34 feet at sea level. Steam siphons will discharge against pressures that are three or four times the operating pressure whether air or steam is used. Air is not as effective as steam in siphons since steam condenses after doing its work and is thus gotten rid of, while air occupies space in the siphon and piping and thus reduces the efficiency of the apparatus. In the absence of direct experiment it is impossible to state exactly how high 40 pounds air pressure will force water.

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(154) (*a*) Some people claim that with the barometer at 30″ and the temperature 70° F., and with a 4″ water pressure through a calibrated orifice of 1½″ diameter, and the thickness of plate $\frac{1}{16}$″, they will get 3,600 cu. ft. of air per hour. Kindly show by example how you would figure the difference in pressure to maintain this constant flow of 3,600 cu. ft. of air per hour at any other reading of the barometer and thermometer. (*b*) How does atmospheric pressure affect the gas in a house line? The pressure is always greatest at the top of the building. Why? (*c*) If you were speaking of 6-oz. gas pressure, would that mean the atmospheric pressure plus the 6-oz. pressure? (*d*) Would Kent's Pocketbook give me this information? Where can it be bought? What is the price? (*e*) In your alphabetic index is a book on how to read meters. Kindly say if they are gas or electric. (*f*) There is a question on meters, No. 313, page 441. How can I get the book?

C. H. B., Pittsburg, Pa.

ANS.—(*a*) With a 4-inch water gauge it would be impossible to obtain a discharge of 3,600 cubic feet of air per hour through an orifice in a thin plate, the orifice having a diameter of 1½ inches, and the discharge being made against atmospheric pressure. The formula for calculating the difference between the initial and discharge pressures, or the gauge pressure necessary to maintain a given velocity of air through an orifice in a thin plate, is as follows:

$$p_2 = p_1 \sqrt[.29]{1 - \frac{1}{t_1}\left(\frac{v}{109\,c}\right)^2}$$

In which, p_1 = the initial pressure (lb. per sq. in.);
p_2 = discharge pressure (lb. per sq. in.);
t_1 = initial temperature of air (Fahr.);
v = velocity of discharge (ft. per sec.);
c = coefficient of contraction at orifice (vena contracta).

A discharge of 3,600 cu. ft. of air per hour is $\frac{3{,}600}{60 \times 60} = 1$ cu. ft. or 1,728 cu. in. per sec. The diameter of the orifice being 1.5 inches, we have for the velocity of discharge,

$$v = \frac{1{,}728}{.7854 \times 1.5^2 \times 12} = 81.49 \text{ ft. per sec.}$$

(nearly). A barometer reading of 30 inches corresponds to an atmospheric pressure of $.49 \times 30 = 14.7$ lb. per sq. in. Assuming for discharge through a circular orifice in a thin plate, $c = .625$, and substituting these values in the above formula, we obtain,

$$p_2 = 14.7 \sqrt[.29]{1 - \frac{1}{70}\left(\frac{81.49}{109 \times .625}\right)^2} = 136.9$$

lb. per sq. in. This pressure corresponds to $\frac{136.9}{5.2} = 26.3$ in. water gauge. (*b*) The gas

pressure, or, in other words, the difference between the gas pressure and the atmospheric pressure, is always greater at the top of a tall building than it is at the bottom when the gas is lighter than air. If, however, the gas be precisely equal to air in weight, i. e., if the specific gravity of the gas is 1, then its relative pressure will be the same at any level. (c) Yes. (d) Kent's Pocketbook contains a vast amount of information on gases. It can be purchased from the Technical Supply Co., Scranton, Pa. Price \$5.00. (e) Electric. (f) By sending 10 cents to this office.

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(155) I should like to know through your Answers to Inquiries what would be a safe load on a post made of 6-inch steam pipe 17 feet long. The pipe is the regular or common thickness (not extra strong). I would like also the rule for working out the safe load on a post of this kind.

F. W. A., Housatonic, Mass.

ANS.—The following formula for determining the ultimate strength of wrought-iron columns is given in Kent's Mechanical Engineers' Pocketbook:

$$p = \frac{f}{1 + C\left(\frac{l}{r}\right)^2},$$

in which

p = ultimate strength in pounds per square inch;

l = length of column in inches;

r = least radius of gyration in inches;

f = 40,000;

$C = \frac{1}{40,000}$ for square end bearings, $\frac{1}{30,000}$ for one pin and one square bearing, and $\frac{1}{20,000}$ for two pin bearings.

The value of p, obtained by means of this formula, must be multiplied by the area of the column in square inches, and this product divided by a suitable factor of safety, in order to obtain the safe load.

Assuming that the pipe is a standard 6-inch wrought-iron pipe with square ends, area of metal, 5.582 square inches, and allowing a factor of safety of 4, which, according to "Kent," is a suitable factor for a dead load, we have $l = 204$, $r = 2.2455$, and

$$p = \frac{40,000}{1 + \frac{1}{40,000} \times \left(\frac{204}{2.2455}\right)^2} = 33,158 \text{ lb.}$$

The safe load for this column is therefore

$$\frac{33,158 \times 5.582}{4} = 46,272 \text{ lb.}$$

The radius of gyration of a pipe is obtained by means of the formula

$$r = \sqrt{\frac{d^2 + d_1^2}{16}}$$

in which r = radius of gyration;

d = outside diameter of pipe;

and d_1 = inside diameter of pipe.

A table in Kent's Mechanical Engineers' Pocketbook gives the value of p for square ends, pin and square ends, and pin ends, when the value of $\frac{l}{r}$ is known.

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(156) (a) Please tell me at what speed a pantograph spindle should run for a router bit to do good work in maple end wood. (b) What is the best way to temper wood-working knives? (c) What is the best grade of steel to use for wood-working knives? J. W. G., Two Rivers, Wis.

ANS.—(a) Concerning the speed of a pantograph spindle for a router bit to work in end grain maple wood, we may say that these machines are usually run at from 8,000 to 9,000 revolutions per minute. (b) Different smiths have different methods for tempering wood-working knives. Probably the most common way is to form the knife to the desired shape, then heat as uniformly as possible, and to no higher a temperature than is absolutely necessary to obtain the desired temper. The knife may be heated in an open fire, but it is better to heat it in a bath of lead or in a gas-fired muffle. After the steel is heated to between a light red and a dull red it is quenched by plunging in water. It is best not to use absolutely cold water. The temper is then drawn upon a piece of hot iron or by holding the bit over the fire. The temper should be drawn to a dark blue. The bit can then be filed without any difficulty. Some smiths use salt water for hardening the bit. (c) Any good grade of steel which is sold by one of the reputable makers of steel for this purpose usually gives good service for bits. Failures in the use of steel occur usually from negligence on the part of the smith rather than on account of bad qualities in the steel, and a man who understands the working of any one of the good standard steels will, as a rule, have no difficulty with it. The Crescent Steel Co., Pittsburg, can probably supply you with the proper grade of steel.

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(157) (a) What is the approximate tensile strength of gun metal, 8C.1T. Of brass, common yellow, 2C.1Z? (b) What is the greatest voltage that can be applied to the coils of a magnet without damaging the insulation of the wire, the wire being No. 22 single cotton covered and having 40 ohms resistance. Could I send 5 amperes through it? (c) Does the phenomena of the rotation of cyclones, whirlwinds, and water hold good for electricity? Cyclones, whirlwinds, and water rotate in a direction opposite to the hands of a watch in the northern hemisphere, and vice versa in the southern hemisphere. Do the magnetic whirls around conductors carrying current circu-

late in an opposite direction in the southern hemisphere to what they do here?

W. F. S., Onward, Ind.

Ans.—(*a*) Gun metal, 27,000 pounds per square inch. Brass, 37,800 pounds per square inch. (*b*) This coil would not likely stand more than .8 amperes continuously. If the winding is not very deep, it might carry 1 ampere without overheating. This assumes that the current is left on all the time. For intermittent service it would carry more than this, but it would not carry 5 amperes for any length of time without burning out. Assuming the safe current to be 1 ampere, the maximum voltage that the coil would stand would be 40 volts. (*c*) No, the magnetic whirls would bear the same relation to the current no matter where the conductor was located.

ELECTRICAL

(158) How would you account for the chipping of one side of each segment of a commutator? It is turning to the left, and the chipped side is, as it were, running from the brushes. There is no sparking, everything seems to be in exceptionally good condition, but for the chipping. It is on a three-phase alternating-current generator, G. E. make, type A. T., class 8. Full load is 605 volts, amperes 96, speed 900. The exciter is of same make, type 1 B, class 2, volts 125, amperes 9. We carry a voltage of 550 with a very unsteady load.

D. R. J., Dedham, Mass.

Ans.—The chipping is probably due to sparking under the brush. This sometimes occurs even though there may not be appreciable sparking at the brush tips, and it seems to be specially liable to take place on commutators having very wide segments as used on alternator rectifiers. It is difficult to stop it, but it can be kept down by seeing that the brushes are kept in good condition. Use a very small amount of vaseline on the commutator to prevent cutting. This chipping action is frequently caused by the brush jumping slightly when passing from segment to segment. If the mica is very hard, it will wear slower than the copper and thus give rise to jumping.

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(159) (*a*) Can the permanent magnet fields of a gas-engine igniter be magnetized from a 125-volt dynamo? If so, please explain. (*b*) How can I connect the wires of a 125-volt dynamo to a gas engine so as to get a spark? Is it as economical as a magneto igniter?

A. W., Sandon, B. C., Can.

Ans.—(*a*) Wind on the magnet frame a large number of turns of about No. 20 cotton-covered copper wire. Connect this coil in series with a group of four 16-candlepower 110-volt lamps (the lamps are connected in multiple) across the 125-volt circuit. Let the current stay on the coil for a few minutes, then cut off the current and unwind the coil. The permanent magnet should be strongly magnetized. (*b*) Connect a group of four lamps, in multiple, in series with a spark coil and the contact points across the line. If a jump spark is desired, connect the primary of the induction coil in series with the four lamps, in multiple, across the line. The secondary terminals lead to the sparking points. It is not so economical.

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(160) (*a*) What percentage of the original magnetism remains in a permanent magnet, of average quality of steel, after the current ceases to flow through the magnetizing coil? (*b*) A coil has a certain number of turns of wire wound on it. The current flowing through it is 10 amperes. If the number of turns is doubled and the same current flows through the coil, will it have the same effect as if the turns remained constant, and if the current were doubled? (*c*) If, with a current of 10 amperes, the number of turns is doubled, will it take a shorter time to magnetize a steel magnet?

F. D., Lyons, Mich.

Ans.—(*a*) No very definite figure can be given. If the magnetizing force does not cause magnetic saturation, a good steel magnet will retain a great part of the magnetism imparted to it. But if the magnetizing force is excessive, the magnet becomes supersaturated and possesses, immediately after the magnetizing force has ceased, a higher degree of magnetism than it is able to retain permanently. A horseshoe magnet will support a greater weight immediately after being magnetized than it will after its armature has once been removed from its poles. (*b*) Yes. The magnetizing force depends on the number of ampere turns. The ampere turns equals the product of the number of amperes of current flowing through the coil and the number of turns of wire in the coil. If the number of turns of wire is doubled and the current kept constant, or if the number of turns is kept constant and the current doubled, the magnetizing force will be doubled. (*c*) Yes, as the magnetizing force has been doubled.

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(161) (*a*) Give rule for rewinding motors for higher voltages. (*b*) Where can I secure a book on the practical construction of alternating-current motors? (*c*) In shunt motors is it well to connect the two fields in parallel?

G. E. M., Kalamazoo, Mich.

Ans.—(*a*) No general rule can be given as the windings must often be modified to suit the construction of the machine. With

higher voltages the number of turns on armature and field will be increased, and the percentage of space occupied by insulation would be greater than on low voltage machines. If there were room to apply the wire the number of turns on the armature would increase as the voltage, i. e., doubling the voltage would require twice the number of turns on the armature. The cross-section of the wire on the armature would be inversely proportional to the voltage, i. e., doubling the voltage would require a wire of half the cross-section because the current output would be only half as great. The shunt field winding should be designed to consume about the same number of watts no matter what the voltage is. The field resistance should therefore increase as the square of the voltage, that is, if the voltage be doubled the resistance should be made four times as great or the fields should be wound with twice as many turns of wire of one-half the former cross-section. Doubling the voltage and making the resistance four times as great makes the field current one half its former value, so that the coils take one-half the current at twice the voltage and the watts consumed remain unaltered. (*b*) The Induction Motor, by Behrend, also Standard Polyphase Apparatus, by Oudin. Technical Supply Co., Scranton, Pa. (*c*) It is better to connect them in series, though if their resistance is equal there is no particular objection to connecting them in multiple.

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(162) (*a*) I have a 14-volt, 14-candle-power battery lamp that I operate by a bichromate plunge battery of 6 tumbler cells, but they will not burn it to give enough light. What would be the most economical way of increasing the light? (*b*) Would it be safe to use this lamp in a laboratory where there are high explosives?
C. J. H., Andover, Ohio.

ANS.—(*a*) If you have any convenient means of charging it, a storage battery would be much more satisfactory than the style of battery you are using. If you cannot get a battery charged, use a larger number of cells similar to those you now have. Use about 16 cells, connecting light in series and placing the two sets of 8 in parallel. (*b*) Yes, but the lamp should be encased in a globe or lantern of some kind to protect it from accidental breakage.

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(163) Will you please explain why the machine of which I send you a full sized sketch will not work as a dynamo. I have had it running with dry-cell batteries but cannot get it to work as a dynamo. The armature is double, shunt wound, and the commutator has four segments. I cannot tell whether there is any difference in size of wire on armature and fields, but that on the armature appears to be the smaller. It is about No. 18. As far as I can tell there are three layers of wire on each magnet.
W. B. K., Cleveland, Ohio.

ANS.—The sketch referred to shows a small machine of the two-pole type. Many of these small machines will run all right as motors, but they will not operate as dynamos because they are not capable of exciting their own fields. Your machine would run as a dynamo if you separately excited it from a battery. When run as a motor its fields are excited from an outside source so that the machine operates all right. We hardly think it is possible to make such a small machine as you show operate as a dynamo and excite its own fields.

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(164) Please explain why you multiply the amperes by the constant 1.73 to find the work in K. W. that a three-phase machine is doing. D. L., Three Rivers, Mass.

ANS.—Your question is hardly stated correctly. In order to obtain the power delivered by a three-phase machine the product of the current and voltage is multiplied by the constant 1.73, assuming that the power is supplied to a non-inductive load. The constant $1.73 = \sqrt{3}$ appears in the formula because the current in the lines is not in phase with the E. M. F. between the lines. For example, suppose the armature has a Y winding, the current in each winding will be equal to the line current C and the E. M. F. between the lines will be $\sqrt{3} \times e$ when e is the E. M. F. generated in one phase. The power developed in one phase will be $e \times C$, and the total power will be $3 \times e \times C$. But $E =$ E. M. F. between the lines $= \sqrt{3} \times e$ or $e = \frac{E}{\sqrt{3}}$, hence power $= 3 \times \frac{E}{\sqrt{3}} \times C = \sqrt{3} \times E \times C = 1.73\ E \times C$.

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(165) (*a*) Are there dynamos in use that are connected to an Edison 3-wire, 220-volt circuit, and feed both sides of the circuit? This in place of the two dynamos, one connected to each side of the circuit. (*b*) What are the essential differences between the windings of a "differentially-wound" motor and a compound-wound dynamo? (*c*) When two motors, alike in all respects, are connected in series, will each motor take half the available activity of the line, that is, half the current as well as half the E. M. F.? (*d*) What is the reason for the flash which occurs when a trolley wheel is brought in contact with (under) a trolley wire, controllers, lights, and heaters all being off? System a 550-volt direct current. (*e*) What would be a good way to magnetize bar magnets? Could they be magnetized on an alternator? Is

high or low voltage, or constancy of current most desirable? (*f*) Is it true that, while the amount of foot-pounds activity that must of necessity be supplied to a steam engine (after it has attained a certain speed) is increased in amount as the square of the speed attained by the engine, the watts activity that must be supplied to a motor increases only in proportion to the speed attained? E. H. O., Philadelphia, Pa.

ANS.—(*a*) Yes; there are a number of different methods in use for operating three-wire systems from a single dynamo. (*b*) In a compound-wound dynamo the series coils and the shunt coils aid each other in magnetizing the field. In the differentially-wound motor, the series and shunt coils oppose each other. The windings are applied in the same way on both machines, but are connected differently as regards each other. (*c*) When two motors are connected in series the current is the same in both. Whether or not the voltage would divide equally between them, depends upon the kind of motors under consideration. If they are series motors connected across a constant potential circuit, their operation will be unstable unless they are connected together so that they have to run at the same speed. If the speeds, field strength, etc. are the same, the voltage will divide equally, and, since the power or activity is given by the product current by voltage, each motor will take half of the power supplied from the line. (*d*) If all the appliances on the car, controllers, lights, heaters, etc. are cut off from the circuit, there will be no flash when the trolley pole is pulled down unless there is a ground somewhere on the trunk wiring of the car. (*e*) You cannot magnetize bar magnets with an alternating current. Place the bar within a coil of wire and send as strong a current through the coil as it will stand without overheating. The magnetizing force depends upon the product of the current sent through the coil and the number of turns on the coil, so that you can use a large number of turns and a small current, or a large current with a small number of turns. The current should be supplied from a direct-current dynamo or a powerful battery. You can also magnetize the bars by bringing them in contact with the pole pieces of a dynamo, though this method is not as satisfactory as the other. (*f*) This question is not quite clear to us. If you increase the speed of an engine and the resistance at the rim of the flywheel remains constant, the activity, or the rate at which the engine does work, increases in direct proportion to the speed and not in proportion to the square of the speed. In other words, other things being equal, the power is proportional to the speed and not to the square of the speed. In the same way if the resistance which has to be overcome at the pulley of a motor remains constant, and if the speed of the motor is increased, the watts which the motor takes from the line must increase in like proportion.

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(166) (*a*) In wiring a large building when the current is taken from the street mains, the voltage being 110 in the mains, is a drop allowed in wiring? If so, how much? (*b*) The wire tables that I have compared with the table in the I. C. S. textbook exceed the carrying capacity of various wires from 50 to 100 amperes. Which is right? (*c*) Would it be practical to install a circuit of 50 bells in an office building, using the ground or gas pipe as a return, instead of wires? If not, why? (*d*) On page 238 of your Mechanics' Memoranda you give a table of carrying capacities of wires, etc. What does it mean by "exposed" and "concealed"? (*e*) Would a telegraph line work as well if the positive side of the battery were grounded instead of the regular way? Would there be a waste of current when the battery is not in use? (*f*) What formula would be used to find the drop in voltage on a battery circuit? J. W. N.,
110 Tremont St., Boston, Mass.

ANS.—(*a*) Yes, some drop must always be allowed because it is impossible to install wires that will have no resistance. About 2 to 3 volts would be a fair allowance. (*b*) The carrying capacity of wires varies greatly, depending upon the location of the wire, whether it is covered or uncovered, etc., so that quite large differences may be found in tables of carrying capacity. In all interior wiring work, the carrying capacity as given by the National Board of Fire Underwriters must be used. This carrying capacity is that referred to in your inquiry (*d*) and given in the Mechanics' Pocket Memoranda (*c*) Yes, this could be done but it would be bad practice to do it, and under some conditions contrary to the Underwriters' rules. A wire should be run for the return. (*d*) The column headed "exposed" gives the allowable capacity when the wire is placed so that the air has free access to it, as in exposed knob or cleat work. When the wire is concealed between floors or in conduit or molding, the current allowance must be less as indicated in the table. (*e*) It makes no difference which side of the battery is connected to ground so long as the groups at each end are in series. (*f*) The drop in voltage in the external circuit is found by multiplying the current by the resistance of the circuit.

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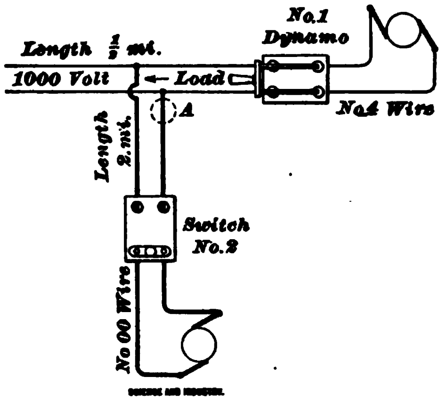
(167) (*a*) When No. 1 dynamo is generating current and No. 2 switch is open, will there be any current in No. 00 circuit? (*b*) If so, how can it be detected? (*c*) If a direct-current circuit of 1 mile length has

a number of wires connected to it and simply left hanging with the other ends not touching anything, will these wires produce any loss? J. W., Union City, Mich.

ANS.—(*a*) No. There will be an electrical pressure between the wires, but no current will flow unless there is some connection between the wires. (*b*) If there were a current it could be detected by inserting an ammeter at *A*. (*c*) No, there would not be



any loss so long as the wires did not come in contact with each other or with anything else.

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(168) Will you kindly explain the following: On several of the rural telephone lines in this vicinity, when the receiver is placed against the mouthpiece, there is a whistling noise all along the line that renders talking almost impossible.

C. G. T., Marshalltown, Ia.

ANS.—If the receiver is held by the hand so that it actually touches any portion of the transmitter, the vibration of the hand may certainly be sufficient to produce a noise, although we are not sure that it would produce a whistling noise. A brief explanation of the whistling noise that is produced when a telephone receiver is held near to the diaphragm of a microphone, but not touching any part of the microphone, is as follows: In the first place, some slight noise is taken up by the microphone and the sound is, in the usual way, given out by the receiver; but since the latter is near the microphone, the air waves set up by the receiver affect the microphone, which in turn again acts upon the receiver, and thus the reaction is maintained for a time. It may be due to the sympathetic vibration of the two diaphragms.

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(169) (*a*) What is the best dielectric for making condensers that will stand a spark from a 1-inch induction coil, the condenser to be connected to the discharge balls? (*b*) Name a good book treating of the development of wireless telephony. (*c*) Is there a substance that has the conductivity of mercury and the stickiness of glycerine? (*d*) Is there any simple, efficient, and cheap automatic battery cut-out for electric gas-lighting work? (*e*) Are the accessories for wireless telegraphy on sale, and if so, by whom? (*f*) What is the best telephone transmitter and receiver manufactured for sale, and by whom sold?

V. R., Washington, D. C.

ANS.—(*a*) Mica is probably the best. To withstand the voltage (20,000 volts) across a 1-inch spark, you should use mica free from holes or other defects, and not less than $\frac{1}{16}$ inch thick. (*b*) There is no book on this subject. You will find something in "History of Wireless Telegraphy," by J. J. Fahie. You will find more in the Electrical World and Engineer for April 5 and 12, 1902, on this subject than in all books put together. (*c*) We do not know of any such substance. (*d*) Firms making gas-lighting apparatus usually make automatic battery cut-outs. Just how simple, efficient, and cheap they are we are unable to say. (*e*) Yes, by several firms, namely, James G. Biddle, Philadelphia; Queen & Co., Philadelphia; Foot-Pierson & Co., New York; and probably others. (*f*) There are now a number of equally good transmitters and receivers. We would not say that any one make is the best. Those for sale by the Ericsson Telephone Co., of New York, are probably as good as any.

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(170) Can holding clips be soldered electrically on to the outside of a coil of steel wire? These clips are one inch wide and are to be fastened to the coil at intervals of one and two inches.

G. E. G., Pittsburg, Pa.

ANS.—We presume that the clip is made of brass or iron and is to be soldered on to the coil and not welded. The inside face of the clip should be tinned. If an alternating-current circuit is available, procure a step-down transformer having its primary coil wound to be connected across the 110-volt alternating-current lines and its secondary wound to give an E. M. F. of 1 or 2 volts, but to have a very large current-carrying capacity. Two terminals may be made which are to be connected to the secondary coil of the special transformer. These terminals may be arranged so that they may press firmly on the ends of the clip on the outside of the coil, or one terminal may be arranged to go on the inside of the coil and the other terminal to press firmly on all portions of the outside of the clip. When the transformer is in action the current from the secondary coil flows through the clip, and as the current is large, the clip

heats and the solder melts. A clamp must be arranged to hold the clip in place till the solder catches and cools, if it is desired to shift the current clamps to a new place immediately. If you must use current from a 110-volt direct-current line, you can do so by connecting the terminals in series with a water rheostat or large wire rheostat. Regulate the current through the terminals by means of the rheostat. The latter method would be quite expensive to operate. If you wish to weld a metal clip to the wire directly without the use of solder, you can probably do so by means of an electric welding outfit. In regard to the necessary apparatus for welding, we would advise you to write to the Thomson Electro-Welding Co., Lynn, Mass.

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(171) (*a*) Can you show by illustrations how a rope driving belt is spliced? How much time is consumed for an average workman to make such a splice? (*b*) How many receivers may be attached to a telephone instrument without impairing its efficiency? I suppose you understand that I mean only one instrument is to be used as a transmitter to eight, nine, or ten persons, more or less. I was thinking an arrangement could be made whereby a talking machine could be made to entertain people through receivers. (*c*) The following characters are on a switchboard of the telephone:

1	*3*			*1*	*2*	*3*	*4*	*4*	*2*
o	o	o	o	o	o	o	o	o	o
C	*C*	*B*	*RC*	*TL*	*TL*	*TL*	*TL*	*C*	*C*

The small circles represent the holes for the plugs. What do the figures above the circles and the letters below them represent? Also the following: *T*, *T*, *P*, *B*, *S*, *S* are on the lower edge of the base board of the cabinet or box containing the call bells. These letters are stamped in the wood opposite each binding post. What do they mean?

D. P., Lawrenceville, Ill.

Ans.—(*a*) The process of rope splicing is fully described and illustrated in an article entitled "Splices, Knots, and Bends," which appeared in the July, 1899, number of the Mechanic Arts Magazine. This can be obtained from this office for 10 cents. More detailed information may be obtained from a book entitled "Splices, Knots, Hitches, Bends, and Lashings," by F. K. Brainard. Price $1.00. For sale by the Technical Supply Co., Scranton, Pa. (*b*) Every receiver added will reduce the intensity of the sound somewhat. However, you can probably work 10 80-ohm receivers in series in one line, provided you have a good powerful transmitter, induction coil, and battery. Your idea would probably work all right. (*c*) Without more information concerning the switchboard, especially the purpose and the kind of telephone system for which it is used, it is difficult to say exactly what the letters represent. However, *C*, *C*, *C*, *C* probably stand for conductors, that is, line wires, the number of each line wire appearing above. Thus there are four lines. *TL* may stand for toll line, there being four of them, numbered *1*, *2*, *3*, *4*. *B* may stand for bell connection, and *R C* for (common) return conductor or line. *T* usually stands for transmitter, *P* for plug or primary winding of induction coil, *B* for bell or battery, *S* for secondary winding of the induction coil. You should read some book on telephony and then you would doubtless understand the meanings of the various letters better.

***

(172) (*a*) Will a dynamo made to work on the floor, work equally well when inverted and suspended from the ceiling? (*b*) How may blasting fuse be fired by means of the electric current? (*c*) How is the act of decomposing water by means of the electric current performed?

J. L. C., Simsbury, Conn.

Ans.—(*a*) There would be difficulty with the bearings, unless the bearings were so designed that the oil would feed to them properly, whether the machine was right side up or inverted. (*b*) Wires are carried from the fuse to the blasting magneto or battery. In the fuse is a very thin platinum wire. This wire gets hot when the current passes through it. This sets fire to the combustible substance used as a priming, which ignites and sets off the gunpowder. (*c*) Two platinum terminals are placed in a jar containing acidulated water. Glass tubes full of water are inverted over the terminal pieces. One terminal piece is connected to one side of a battery, and the other terminal to the other side of the battery. When a current passes, the water is decomposed and oxygen gas will be evolved in the tube over the terminal connected to the positive side of the battery, and hydrogen gas will be evolved in the tube over the terminal connected to the negative side of the battery.

***

(173) Please inform me as to the best way of regulating a current of 4 volts and 65 amperes generated by a dynamo, to be used for copper electroplating. The bath contains about 65 gallons of copper solution. I have been using the full current from the dynamo, and the deposit has been quite unsatisfactory, being dark and very coarse, also easily rubbed off. Should the current be weakened, and how?

C. S. I., Hampton, Va.

Ans.—Connect in between one of the plating tank wires and one of the terminals of the plating dynamo, a number of coils of No. 3 Washburn & Moen iron wire. Probably 10 or 15 feet of this wire would be enough. Wind up the wire into an open spiral coil. Fasten one end of this resist-

ance coil to the dynamo terminal and arrange a clamp on the tank wire, so that the tank wire may be clamped to the resistance coil at any desired point. Support the resistance coil so that the turns of wire of the coil do not touch each other, and see that the coil does not touch any wood or other easily ignited material. The current can be weakened by increasing the number of turns of wire between the dynamo terminal and the clamp on the tank wire.

***

(174) How can a Hughes induction balance be made, similar to the one described and illustrated in Hou-ton's Electrical Dictionary? J. F. G., Navarre, O.

ANS.—Turn the bobbins out of boxwood. Make them about 3 inches in diameter and about $\frac{3}{4}$ inch high, outside dimensions. Wind each bobbin with 300 feet of No. 32 copper wire. You would probably be able to obtain the whole outfit from Queen & Co., Philadelphia, Pa., but the apparatus is not difficult to construct. The interrupter may be made by driving a number of small nails into a wooden disk, which is provided with a handle, so that it may be turned. File the heads of the nails off. Arrange a piece of spring brass to make contact with the nails. Mount the interrupter on a separate board from the board on which the coils are placed. The coils *B* and *D* can be mounted on the coil board. Do not use nails or screws to fasten the coils to the board. Mount the coils upright on the board and fasten them by wooden pins passing through the base board and up into the edge of the bobbin flanges. The coils *B* and *D* can be mounted about 2 inches from each other. Instead of mounting coils *A* and *C* directly on the base board, mount either one or both on flat strips of wood that may be arranged to slide on the base board. The distance between the coils *A* and *C* can thus be varied either by hand or by using a wooden rod with a thread cut on it. Coils *A* and *C* are mounted in an upright position. All four coils could be arranged to lie horizontally, the secondary coil directly above the primary coils, but it would probably be easier to mount and adjust them when mounted in an upright position. Coils *A* and *B* should be about 18 inches apart. Coils *C* and *D* should also be 18 inches apart. Connect up the apparatus as shown in the illustration in the dictionary. A telephone receiver may be purchased from the Western Electric Co., Chicago, Ill. Directions for making a telephone receiver are given in a book entitled "Electrical Designs," published by the American Electrician Co., New York City. For further information in regard to the Hughes induction balance we would refer you to "The Alternate Current Transformer in Theory and Practice," by J. A. Fleming.

(175) Will you kindly give diagram and explanation of the open-circuit system of telegraphing, as used in foreign countries? The wiring principle is the part I most desire. L. G. H., Omaha, Neb.

ANS.—The principle of the Morse open-circuit telegraph system, as used in foreign countries, is shown in the accompanying figure. When all keys are at rest in their normal position, that is, when no message is being sent, all batteries are on open circuit, although all the relays are connected in series in the circuit. Thus, normally, no current flows through the line or local sounder circuits, from which fact the name is derived. When a message is to be sent, the sending operator closes his key, the battery at his station is thereby connected in the line circuit, his own relay is cut out, but relays at all other stations respond to the current from the one battery. A fuller description of this system may be found in "American Telegraphy," by Maver. This book you can purchase from the Technical Supply Co., of Scranton, Pa., for $3.50.

MISCELLANEOUS

(176) The accompanying sketch, Fig. 1, shows a 2-horsepower boiler used for heating purposes. Kindly inform me whether my drip pipes are connected right and

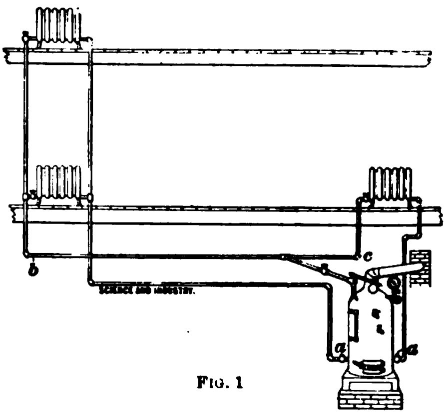


FIG. 1

whether I need a check-valve at *a a* near the bottom of the boiler where the drip pipes are connected. E. S., Eddystone, Pa.

ANS.—We see no good reason why your drip pipes should give you trouble if you place a check-valve upon each to prevent water from backing up from the boiler and flooding the radiators when the radiator valves are closed. You show only one valve at each radiator. Owing to the fact that the

radiators are all connected on the two-pipe plan, you should have a valve on each return or drip pipe close to each radiator. Then you will not have to depend upon the check-valves except when the person who shuts off steam from a radiator neglects to shut off

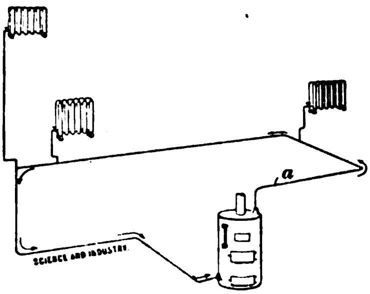


FIG. 2

the drip valve also. Water of condensation, however, will accumulate at b and perhaps also at c and cause water hammer. This can be avoided by taking drips from these points and connecting them to the return pipes below the water-line of the boiler. The best way to pipe a small job like the one shown is by the one-pipe system. Fig. 2 shows how this may be accomplished. The steam main a forms a continuous circuit, as shown by arrows, and each radiator has only one pipe connection. This arrangement is more simple, more safe, and more satisfactory than your arrangement shown in Fig. 1.

***

(177) I desire to know if a dry-rubble wall, built as shown in Fig. 1, will stand. The wall is a retaining wall, and is built about 4 feet from the end of a barn. The grade line is marked in the sketch. It is the intention to fill in against the side furthest from the barn, and grade back to form a driveway into the barn. The ground is a

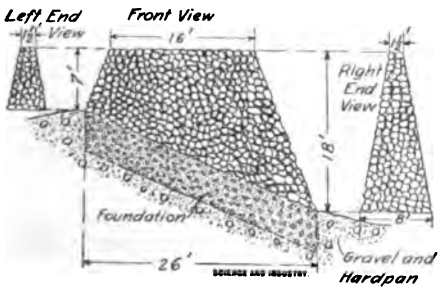


FIG. 1

gravelly loam, and I desire to know whether the water will soak into the dirt at the top of the wall and in freezing tend to push the wall over, and also whether the wall should be laid up with mortar. Is the design of the wall correct, and should the foundations be laid more than 4 feet deep and wider than the wall? L. P. H., Peterboro, N. Y.

ANS.—It is extremely bad practice to construct any wall with the footings on a sloping bed; it would be especially bad to construct a dry wall in this way. It would be far preferable to place the footings on a level bed, as shown in Fig. 2. The excavation can be so arranged that the footing may be constructed in this manner. In our opinion there is less likelihood of the dry wall being overturned by frost than there would be of a wall laid up close with mortar, since the spaces between the stones allow any moisture to run off and precludes the possibility of any great amount of water collecting back of the wall. The wall can be constructed dry, but we would recommend that a course of headers or binders be laid in the wall every 4 or 5 feet, as shown in Fig. 2 at a. It would be well to lay up this course with mortar and to level off the top with a bed of mortar. This is a precaution that would be necessary with such a high wall constructed dry. We would likewise suggest that the top course or two be laid with mortar. The

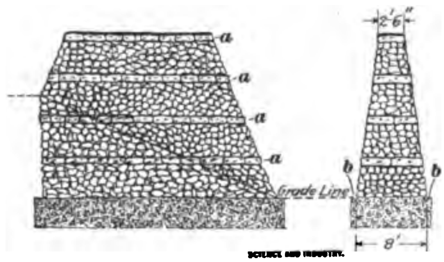


FIG. 2

wall should be somewhat wider at the top than you show. We think 2 feet 6 inches or 3 feet would be better. If the ends of the girders carrying the causeway into the barn are thoroughly built into the wall, and the other ends well spiked to the sill of the barn, they will assist greatly in resisting the pressure of the earth against the wall. The width of the footing at the bottom, 8 feet, is ample. We would advise extending the footing course about 4 inches on each side, as designated at b in Fig. 2.

***

(178) (a) Fig 1 shows in plan at A and elevation at B an arrangement by which I propose to heat three steam radiators from my kitchen range. I intend to disconnect them from the present steam-heating system and connect them up as shown to a 52-gallon boiler in the kitchen. The range is of the hotel type and produces more hot water than is required at the plumbing fixtures. Is the plan a feasible one? (b) When we get up 6 or 7 pounds of steam in our steam

boiler, the water siphons out of the boiler. How can I fix it to avoid this?

H. C. M., Philadelphia, Pa.

ANS.—(*a*) The arrangement shown in your illustration, Fig. 1, will not work satisfactorily. The water will certainly circulate through the pipe line shown from the boiler to the radiator connections and back to the boiler again, but there will be no circulation between this loop and the radiators. The radiators, therefore, will remain cold. To overcome this difficulty, it will be necessary to employ two pipe connections to your radiators and in a general way to pipe the system as shown in Fig. 2, which does not include the lower radiator. We think it advisable for you to leave the lower radiator connected to your present steam-heating plant and heat the two upper radiators only from the kitchen boiler, because then you will be sure of a positive circulation. A good serviceable circulation cannot always be obtained in the lower radiator unless you allow the water that flows through the upper radiators to flow through the lower radiator as it returns to the boiler; even then there will be times

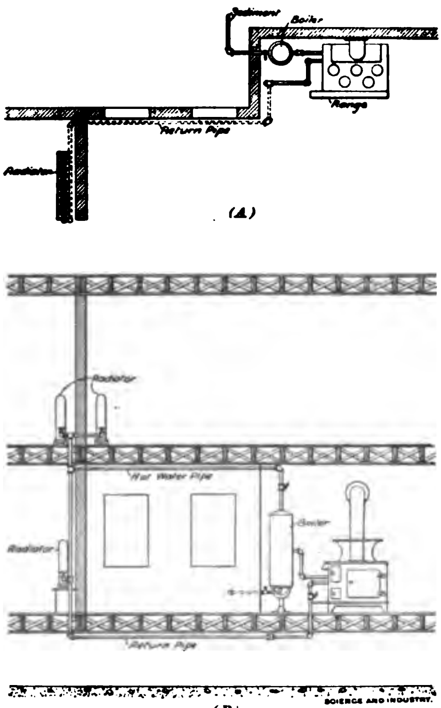


FIG. 1

when the lower radiator will be cold when it should be warm. This is due to hot water being drawn from the kitchen boiler. You do not require an expansion tank over the radiators, but you must be sure that the water pressure is not great enough to burst your radiators. (*b*) It is difficult for us to state precisely what causes the water to

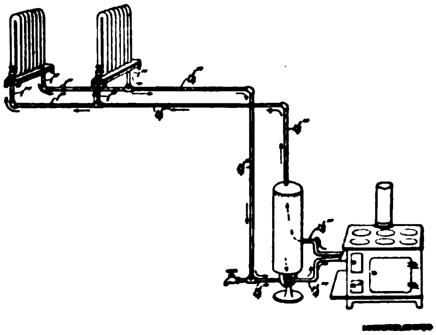


FIG. 2

leave your boiler. It would appear, however, that the steam mains are too small, or are in some way obstructed. This lowers the pressure at the extreme end of the heating mains and causes water to back up through the return pipes into the lowest radiators. You can remedy this trouble by either increasing the size of the steam mains or lowering the boiler.

***

(179) A and B dig a ditch 100 feet long, for which they receive $50.00 each. B receives 25 cents per foot more than A for the amount he digs. How much does each dig and what is the price per foot that each receives?

E. M., Marysville, Mont.

ANS.—

Let $x =$ number of feet A digs;

$y =$ number of cents per foot A receives.

Then,

$y + 25 =$ number of cents per foot B receives.

$100 - x =$ number of feet B digs;

From the conditions of problem,

$$xy = 50$$

$$(100 - x)(y + 25) = 50$$

Solving these equations,

$$x - 56.155;\ y = 89.04$$

Whence,

$$100 - x = 43.845;\ y + 25 = 114.04.$$

Hence, A digs 56.155 feet and receives $.8904 per foot; B digs 43.845 feet and receives $1.1404 per foot.

***

(180) When the length of the arc and chord of a segment are given, find the height of the segment.

W. H. P., Newark, N. J.

ANS.—Let $l =$ length of arc;

$a =$ length of chord;

and $h =$ height of segment.

Then, the approximate height of the segment is given by the formula,

$$h = \tfrac{1}{8}\sqrt{3(l-a)(3l+5a)}.$$

STANDARD TAP DRILLS

Tap	Drill	Tap	Drill	Tap	Drill	Tap	Drill
$\frac{1}{4}$	$\frac{3}{16}$	1	$\frac{27}{32}$	$2\frac{1}{4}$	$1\frac{31}{32}$	$4\frac{1}{2}$	$4\frac{1}{16}$
$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{1}{8}$	$\frac{15}{16}$	$2\frac{1}{2}$	$2\frac{3}{16}$	$4\frac{3}{4}$	$4\frac{5}{16}$
$\frac{3}{8}$	$\frac{9}{32}$	$1\frac{1}{4}$	$1\frac{1}{16}$	$2\frac{3}{4}$	$2\frac{7}{16}$	5	$4\frac{1}{2}$
$\frac{7}{16}$	$\frac{11}{32}$	$1\frac{3}{8}$	$1\frac{5}{32}$	3	$2\frac{21}{32}$	$5\frac{1}{4}$	$4\frac{3}{4}$
$\frac{1}{2}$	$\frac{13}{32}$	$1\frac{1}{2}$	$1\frac{9}{32}$	$3\frac{1}{4}$	$2\frac{29}{32}$	$5\frac{1}{2}$	5
$\frac{9}{16}$	$\frac{7}{16}$	$1\frac{5}{8}$	$1\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{1}{8}$	$5\frac{3}{4}$	$5\frac{1}{4}$
$\frac{5}{8}$	$\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{5}{16}$	6	$5\frac{7}{16}$
$\frac{3}{4}$	$\frac{5}{8}$	$1\frac{7}{8}$	$1\frac{5}{8}$	4	$3\frac{9}{16}$	7	
$\frac{7}{8}$	$\frac{23}{32}$	2	$1\frac{23}{32}$	$4\frac{1}{4}$	$3\frac{13}{16}$	8	

WROUGHT-IRON PIPE MEASUREMENT

Size of Pipe	Size of Tapping	Outside of Thread	Length of Thread	No. of Threads per In.
$\frac{1}{8}$	$\frac{21}{64}$	$\frac{13}{32}$	$\frac{9}{32}$	27
$\frac{1}{4}$	$\frac{29}{64}$	$\frac{35}{64}$	$\frac{3}{8}$	18
$\frac{3}{8}$	$\frac{19}{32}$	$\frac{27}{32}$	$\frac{7}{16}$	18
$\frac{1}{2}$	$\frac{23}{32}$	$\frac{27}{32}$	$\frac{1}{2}$	14
$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{1}{16}$	$\frac{9}{16}$	14
1	$1\frac{3}{16}$	$1\frac{10}{32}$	$\frac{5}{8}$	$11\frac{1}{2}$
$1\frac{1}{4}$	$1\frac{15}{32}$	$1\frac{5}{8}$	$\frac{11}{16}$	$11\frac{1}{2}$
$1\frac{1}{2}$	$1\frac{23}{32}$	$1\frac{15}{16}$	$\frac{13}{16}$	$11\frac{1}{2}$
2	$2\frac{3}{16}$	$2\frac{3}{8}$	$\frac{7}{8}$	$11\frac{1}{2}$
$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{7}{8}$	1	8
3	$3\frac{1}{4}$	$3\frac{1}{2}$	1	8
$3\frac{1}{2}$	$3\frac{3}{4}$	4	$1\frac{1}{16}$	8
4	$4\frac{1}{4}$	$4\frac{1}{2}$	$1\frac{1}{8}$	8
$4\frac{1}{2}$	$4\frac{3}{4}$	5	$1\frac{1}{4}$	8
5	$5\frac{5}{16}$	$5\frac{9}{16}$	$1\frac{1}{4}$	8
6	$6\frac{5}{16}$	$6\frac{5}{8}$	$1\frac{3}{8}$	8
7	$7\frac{3}{8}$	$7\frac{5}{8}$	$1\frac{1}{2}$	8
8	$8\frac{3}{8}$	$8\frac{5}{8}$	$1\frac{5}{8}$	8
10	$10\frac{13}{32}$	$10\frac{3}{4}$	$1\frac{3}{4}$	8

SHAFTING FORMULAS

RULE.—Multiply the tabular number in column headed $\frac{\text{H. P.}}{N}$ by the number of revolutions per minute made by the shaft. Result = horsepower shaft will transmit.

Diameter Inches	$\frac{\text{H. P.}}{N}$	Diameter Inches	$\frac{\text{H. P.}}{N}$	Diameter Inches	$\frac{\text{H. P.}}{N}$
$1\frac{3}{4}$	.0623	$3\frac{3}{4}$	.6132	$6\frac{1}{2}$	3.1944
2	.093	4	.7442	7	3.9888
$2\frac{1}{4}$	.1325	$4\frac{1}{4}$	.8930	$7\frac{1}{2}$	4.9056
$2\frac{1}{2}$	.1817	$4\frac{1}{2}$	1.06	8	5.9536
$2\frac{3}{4}$	.2418	$4\frac{3}{4}$	1.247	9	8.48
3	.3139	5	1.4536	10	11.6288
$3\frac{1}{4}$	.3993	$5\frac{1}{2}$	1.9344	11	15.4752
$3\frac{1}{2}$	.4986	6	2.5112	12	20.0896

TWISTING MOMENT

To find the mean twisting moment for countershafting in statical inch pounds: $T = 63{,}024\frac{\text{H. P.}}{N}$, where T = twisting moment, H. P. = horsepower, and N = number of revolutions per minute.

COMPLIMENTS OF

SCIENCE AND INDUSTRY

SCRANTON, PA.

SCIENCE AND INDUSTRY

Vol. VII July, 1902 No. 7

SOME POINTS ON THE RUNNING AND MANAGEMENT OF BELTS—I

ALTHOUGH belts and shaftings are, comparatively speaking, rapidly being displaced by electrical means for distributing and transmitting power, the majority of factories, mills, and a very large number of electric light and power stations still use belts, and no doubt this method of transmitting power will remain a familiar equipment for many years to come. Persons living in the large cities are apt to conclude that the days of belt drives are numbered, and that belt-driven machinery, everywhere and for all purposes, will, in a comparatively short time, become a back number in up-to-date installations. If all belts were run and cared for as some are, the transition period would indeed be short, and the time for making the change from belt to electrically direct-driven machinery would be welcomed by power users both large and small. On the other hand, if all belts were operated and maintained as some others are, the introduction of electrical means for transmitting and distributing power for certain purposes would undoubtedly progress much more slowly than it does at present.

The line shaft loaded with perhaps half a hundred heavy pulleys, and the numerous countershafts employed for obtaining a change of speed to meet the requirements of individual machines, represent a dead load which must be provided for whether the salable output is zero or the maximum. This represents an expenditure of power from which no returns are obtained or even expected. This condition of things may be compared to a person paying twenty-five cents for the opportunity of spending a dollar, the returns being due to the expenditure of the dollar while the twenty-five cents is looked upon as an unnecessary necessity. This is evidently contradictory, because that which is a necessity cannot be properly called unnecessary, yet this is exactly the case with belt-driven plants in which the belts are not run to the best advantage and maintained in such a manner as to reduce the unnecessary losses to a minimum. The coal required to carry the dead load is, figuratively speaking, the twenty-five cents previously referred to, and the amount required to produce salable goods represents the expenditure of the dollar.

The actual net saving to be realized by changing from the belt-driven to the electrically-driven system varies in each case and will depend to a great extent upon the management of the belts and the possibility of reducing the unnecessary belt losses. There is with belt drives as with motor efficiencies a figure beyond which it is im-

practicable to go in every-day practice, but it requires close study and careful management, as well as considerable skill, to reach the highest efficiency with belt drives.

Doping the belts now and then with almost anything that happens to be handy, and lacing belts in any manner that will cause them to hold together and run, will not bring the desired results, and as the natural consequence the change from belt- to electrically-driven machinery will appear to be the more practicable means of economizing.

During the past three years some interesting data have been obtained relative to the possibility of reducing fractional losses in belt-driven establishments by a careful and inexpensive treatment of the belts. In one factory the dead load amounted to nearly 60 per cent. of the total, that is, only 40 per cent. of the total load on the engine was utilized in producing salable goods. Another case showed a dead load of 47 per cent., another of 39 per cent., and another of only 26 per cent. The dead loads varied all the way from the lowest to the highest figures named, and were a great surprise to the owners as well as to the engineers. The dead loads in these cases were obtained by taking indicator diagrams at regular intervals for several days, then certain departments were alternately run and cut out and the results averaged, practically the same results being obtained by both methods in nearly every instance.

A crusade against belt evils reduced the figures in the first case to about 42 per cent., in the second case it was reduced to 30 per cent., in the third to 23 per cent., and in the fourth one mentioned to 21 per cent.

Much can be done towards reducing the dead load by a judicious distribution of the machinery and by the introduction of clutches and clutch pulleys. It is quite possible that the losses referred to could have been reduced another 10 or 15 per cent. had friction clutches been introduced at the proper points.

It seldom pays to jump at conclusions in matters mechanical, and it is with belts as with many other devices, viz., it requires careful study oftentimes, and a good stock of sound "horse sense" to be able to locate difficulties and remove them.

Persons who have given the experiment a fair trial are of the opinion that a considerable saving of fuel and other expenses incident to belt drives is obtained by placing all the belts and shafting in charge of one man, who generally goes by the name of the "belt doctor." This person may, and frequently does, have other duties assigned him, but no other person has anything to do with the maintenance of the belts, pulleys, and shafting. If the "belt doctor" understands his business as he should, there is no reason why the dead load should not be reduced to a minimum, and a considerable saving be thus effected.

Belts are frequently ordered without reference to the conditions under which they are to run, and when received they are enrolled, measured, and put upon pulleys with no thought concerning the condition of the leather, some persons taking it for granted that a new belt fresh from the dealer or the factory warehouse is in the proper condition to be put upon the pulleys and is ready for service. The belt is drawn up tightly with belt clamps, and laced or sewed, and immediately started under a heavy load, and from this time on trouble is not lacking, and the belt frequently proves a source of considerable expense before the right thing is done. How much better it would be if some of the painstaking work put

upon old belts after the troublesome periods have, perhaps, been past were to be put upon new belts, and many of the troubles common to this form of transmission thus avoided. Unless great care is exercised in manipulating the clamps a belt will be stretched more on one side than the other, and consequently one side will be longer than the other, which generally gives rise to a variety of troubles, and attempting to correct one usually produces another. If the belt runs off, or to one side of the pulleys, the countershaft is sometimes adjusted to cause it to keep the center of the pulleys, and this oftentimes produces hot bearings. These are due to the belt directly, and to the man who put it on indirectly, in not using good judgment to start with.

Tightening belts increases the friction of the bearings, and consequently the power required to run a mill or factory increases very rapidly when tightening the belts. Tightening the belts not only increases the power consumed from which no adequate returns can be expected due to increasing the dead load, but it shortens the life of the belts by bringing about conditions demanding extraordinary treatment, which is too often far from beneficial in the long run. Where a belt is rendered as soft and pliable when new as it is desired to have it later on, perhaps after the belt has been to a great extent ruined, many of the initial troubles with belts will be avoided, and the subsequent treatment will then be less severe and injurious.

A belt will stretch to some extent when first put on; this cannot be entirely avoided, but it is not wise to attempt to take out all the stretch, as it is called, at any one time, as is frequently done. Considerable time may be saved by so doing, it is true, but it generally happens that the injury to the belt amounts to considerably more than the time saved. When a "belt doctor" is employed, the saving of a few minutes now and then is not as important as when skilled workmen are required to leave their work in order to keep the belts in order.

A new belt will require frequent relacing when properly handled and cared for, because the slack will be removed a little at a time, as it occurs, so as to keep the belt at about the same tension, which should never be greater than is necessary to carry the load without noticeable slipping.

There are a number of belt dressings and suitable oils on the market, which, when properly used and at the proper time, will save the first cost and make a substantial saving in fuel besides. It is not necessary to employ the most expensive dressings in order to secure satisfactory results. A very satisfactory dressing consists of pure tallow, which should be heated to about 100° F., and thoroughly rubbed into the leather, afterward allowing the belt to dry thoroughly before being put under tension. The oil of the tallow passes into the tallow of the leather and serves to soften it while the stearin is left on the outside, to fill the pores and leaves a smooth surface, the adhesiveness of which, when passing over the pulleys, is equal to that produced by many of the most expensive dressings. When dressing with warm tallow, a little resin will sometimes aid belts which run in wet or damp places, in preserving the strength of the belt. The exact amount of the resin can only be determined by experiment, and it will be much better to put in too little rather than too much at the outstart. When the surface of the belt feels sticky after having been allowed to dry for from 4 to 5 hours, too much resin has been used. The degree of adhesion

is not proportional to the degree of stickiness of the surface, and if this fact were better appreciated less resin would be used as a belt dressing, or rather as a dope. The best time to treat a belt in a factory running 6 days a week is Sunday morning, because it affords ample time for thorough rubbing and plenty of time for the belt to dry before the load is put on.

Another simple and inexpensive dressing is vaseline, which is frequently used with good results where belts run in cool or damp places. The application is the same as with tallow. The latter dressing does not give as good results when the belts run close to the ceiling in highly heated rooms or when otherwise exposed to considerable heat.

Belts that have become so hard and dry as to be in danger of cracking may be treated with neat's-foot oil mixed with a small quantity of resin, the latter tending to prevent the oil from injuring the belt in any way and helping to preserve the leather. The degree of stickiness should govern the quantity of resin to be used, which will be found to be very small. Penetrating oils should be avoided, and it is not good practice to soak belts in water, as is sometimes done, previous to treating them with oil or other dressing.

The treatment of new belts consists of an application of warm tallow or a mixture of tallow and oil with a little beeswax added. This is to be rubbed in and the belt permitted to dry thoroughly before being put onto the pulleys. Castor-oil dressing may be obtained properly prepared for use on belts. This may be applied with a brush or rag while the belt is in motion, if necessary. Belt dressings of any kind should not be applied too liberally, and a "belt doctor" who understands his business will not try to treat a belt in from 5 to 10 minutes. Many persons keep pouring on the oil until the desired result is obtained or until the belt begins to behave worse than at first, evidently believing that as soon as the belt has received as much oil as it needs all trouble will cease. A house may be painted by pouring the paint over the roof, but the distribution will be decidedly poor and the result far from what is desired. It is practically the same with a belt; it is the very poor and uneven distribution obtained by pouring on the dressing that tends to make a belt run worse instead of better when treated when it is in motion.

When a liquid or semi-liquid dressing is applied the belt is liable to stretch unevenly owing to the constantly varying tension to which it is subjected and to the fact that it is impossible to apply the dressing evenly and simultaneously across the belt, which, of course, should be done when the belt is treated while subjected to tension.

The running quality of a belt depends largely upon the size of the pulleys over which it runs which consequently influences the amount of power it can transmit economically. The speed of the belt also affects its ability to transmit power and has an important influence upon the size of belt required. It is not a difficult matter to figure out the speed at which a belt should give the best results, but it is when we attempt to apply the result of the calculation that difficulties are oftentimes encountered. When considering the belt only, the more economical speed will be approximately 3,500 feet per minute, that is to say, the greatest power can be transmitted with the least cost, all things considered, at about this speed. It is, however, difficult to obtain this speed in practice, because with a few exceptions one

pulley will be found to be smaller, perhaps very much smaller, than the other and as the speed of either the driving or the driven shaft, sometimes both, must remain unchanged, it becomes impossible to get the best speed for the belt, that is, the speed at which we might transmit the greatest number of horsepower with the least expense for belting. It is the exception rather than the rule when a belt can be run at the most economical speed from this view point. If both pulleys were of approximately the same size, say, from 44 to 50 inches diameter, then a speed of 3,500 feet per minute might be more readily obtained, but on the other hand should one pulley be found to be 4 feet in diameter and the other from 8 to 12 inches, the belt could not be satisfactorily run at this speed; the *best* speed in this case would necessarily be that which would best adapt this means of transmitting power to the existing conditions.

It is in work of this kind, viz., finding out just what can be done and the best size of belts and pulleys to use to meet the conditions, that the "belt doctor" can apply a little simple arithmetic to good advantage, and in many cases can effect a substantial saving in not only the first cost of belts, pulleys, and shafting, but also in the cost of maintenance. As an illustration of where it will be found impracticable to employ high belt speeds, take a small blower running at high speed, as is generally the case, the blower being driven by the line shaft revolving at a comparatively low speed, through a countershaft, which is nearly always required except where the line shaft is operated at an unusually high speed. The belt from the countershaft to the blower may be run at 3,500 feet per minute, but the one from the line shaft could not possibly be run at anywhere near this speed. When driving a line shaft by a high-speed engine or electric motor, the main belt is quite apt to have a speed approaching the ideal but the speed of all the others will probably be considerably below the ideal speed. A medium speed may be obtained by changing the sizes of the pulleys, that is, it is possible many times to thus increase the speed of the belt to a point nearer that which would be obtained by using a single belt from the prime mover to the last of the driven pulleys. A belt drive, however, to be reliable and free from excessive loss by slipping, should not have too great a difference between the diameters of the driving and driven pulleys. Suppose a shaft making 180 revolutions per minute drives a spindle making 2,600 revolutions, and that the driving pulley is 60 inches in diameter and the spindle 4 inches; it is evident the difference will be too great because the slippage at the small pulley or spindle will be excessive unless the belt be of unusual length and width and is very thin, although the speed would be 2,827.5 feet per minute, which in itself would be desirable.

By introducing two countershafts having a 60-inch pulley on the first shaft driving a 40-inch pulley on the second, then a 36-inch driving a 16-inch, and a 24-inch driving a 5½-inch pulley on the spindle, the speed of the belts will be, respectively, 2,345, 2,543, and 3,815 feet per minute, which more nearly approaches the speed considered best for all-around economy. This illustration is made to show that by changing the pulleys, countershaft, etc., it is oftentimes possible to increase the speed of the belt, and thus be able to use a lighter, narrower, and cheaper belt without necessarily interfering with the ultimate life of the belt

or the reliability of the transmission system. Whether it will be advisable to make these changes and to secure the higher speed will depend upon the conditions existing, and this is one instance where a trained "belt doctor" may prove a valuable acquisition to the factory force.

In arranging the drive for a large factory it is not impossible to get the more economical speed for the main driving belt, but if the establishment is a machine shop employing the usual large number of belts, it is quite probable that less than 10 per cent. of the belts can be run even at one-quarter the speed laid down as the best for economy in the cost of belts for transmitting a given horsepower. The question of speed evidently requires careful working out in order to be able to select a belt that will transmit the greatest horsepower with the least cost of belting and pulleys.

A belt 1 inch wide under a tension of 60 pounds and traveling 550 feet per minute will transmit 1 horsepower, and if the speed be increased to 1,100 feet per minute, the stress may be reduced to 30 pounds and still transmit the same power. This indicates that by doubling the speed of the belt one of three things may be accomplished; first, the stress may be reduced one-half, or second, the width of the belt may be reduced one-half, or third, the load which the belt will carry may be doubled.

A rule in common use is that a belt 1 inch wide traveling 1,000 feet per minute will transmit 1 horsepower. The stress per inch of width in this case is obviously 33 pounds. This of course is assuming that the belt runs under good conditions, which do not always exist, and it must be remembered that it is the conditions that effect the efficiency of the belt, not the figures, so that when figuring on a belt drive it is advisable to endeavor to secure conditions as nearly right as the probability of being able to maintain these conditions will warrant; that is to say, do not calculate upon an arc of contact greater than can reasonably be maintained under the influences of temperature, moisture, and load, remembering that the arc of contact is apt to decrease rapidly at high speeds when the load increases. The average load should not be employed when calculating the requirements of a belt, for when the maximum load is put on the effect of temperature, moisture, and of the condition of the pulley surfaces may tend to lessen adhesion and consequently the efficiency of the belt for transmitting power and at a time when the highest possible efficiency is needed. The degree of adhesion is practically independent of the diameter of the pulleys and the extent of belt surface in contact with the pulley. A belt will be found to slip as readily on a pulley 6 feet in diameter as it will on one 4 or 5 inches in diameter, provided the condition of the pulley surfaces, the arc of contact, the tension, and the speed of the belt remain the same in both cases.

The required width of a single and double belt to transmit a given number of horsepower may be found by the following formulas: $\frac{\text{H. P. } 2{,}800}{D\,R} =$ width of single belt, and $\frac{\text{H. P. } 2{,}100}{D\,R} =$ width of double belt, in which D represents the diameter of the pulley in inches, and R the number of revolutions per minute. These formulas are based upon a tension of 60 pounds per inch of width for double belt, and 45 pounds per inch of width for single belt, which will be found conservative figures for general use. To illustrate

the practical application of the formulas, assume that 125 horsepower is to be transmitted by means of a pulley 60 inches in diameter making 200 revolutions per minute. The width of a single belt is $\frac{125 \times 2,800}{60 \times 200} = 29.1$ inches, or 29 inches in round numbers, and the width of a double belt is $\frac{125 \times 2,100}{60 \times 200} =$ 21.87 inches, or practically a 22-inch belt. The latter calculation calls for a 22-inch belt to transmit 125 horsepower, and it will be noticed that nothing is said about the conditions under which the belt is to be run, consequently it may be properly assumed that the conditions are favorable to the best results. But the conditions are not always what they should be or what they might be were sufficient pains taken to make them as good as the facilities at hand will permit. In order to make a suitable allowance for conditions, which do not even approximate the ideal, demands considerable practical experience, and oftentimes more than the mechanic operating a machine or the engineer who is engaged in the production of power can reasonably be expected to have, and for this reason conservative figures are preferable. When belts are to run close to the ceiling in warm rooms and subjected to the accumulations of dust and dirt, high temperatures and an occasional overload, some allowance must be made, for the tendency of these conditions is to lessen the efficiency of a belt to a considerable extent. When a belt runs in a dry, hot place it soon becomes hard and stiff, the surface becoming glossy, and the tendency to slip is no less than the tendency to crack, both of which prove highly injurious in a remarkably short time. In a case of this kind one of two things must be done in order to be able to transmit the same power without further injury to the belt, viz., either a tightener may be employed for the purpose of increasing the tension, thus increasing for a time the degree of adhesion, or the belt must be treated with a good dressing. The latter method is, of course, the better, because in this case the proper degree of adhesion may be secured without increasing the initial stress, which is a desirable thing to do whenever practicable, for it is evident that the lower the unnecessary stresses in a belt can be kept the less friction will there be at the bearings, and consequently a corresponding amount of power and fuel will be saved while transmitting the same number of horsepower.

(To be Continued.)

SPECIFIC GRAVITY

Specific gravity is the relative density of two substances, one of which is understood to be unity; for convenience the latter is taken as water. Then when we speak of the specific gravity of galena as being 7.5 we mean that galena is 7.5 times as dense as water. Weight has nothing to do with the term specific gravity. But knowing that galena is 7.5 times denser than water and knowing that a cubic foot of water weighs 62.4 pounds ($62\frac{1}{2}$ roughly) then by multiplying the latter figure by 7.5 we can ascertain the weight of a cubic foot of solid galena. Briefly, therefore, specific gravity is a ratio of density and not a weight.

MEAN EFFECTIVE PRESSURE

WALTER W. EDWARDS

SO MUCH has been written on indicators and indicator cards that it would seem as if it would be impossible to add anything to the vast store of knowledge that has accumulated since the time of Watt. Every line and every point of the card has been scrutinized by careful observers

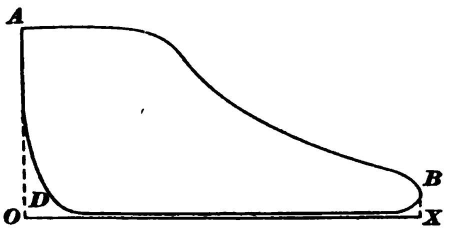


FIG. 1—DIAGRAM FROM HEAD-END OF SIMPLE NON-CONDENSING ENGINE, HALF SIZE.

until it would seem that everything had been noted and recorded. The mean effective pressure is defined by all text-books as the average of all the varying pressure on one side of the piston minus the average of all the back pressure that is exerted on the other side, and is computed by dividing the area of the card by the length and multiplying by the scale of the spring; or it may be obtained by dividing the card into any number of equal parts and then getting the average length of the ordinates erected at the middle point of each of these divisions. This average length multiplied by the scale of the spring gives the mean effective pressure.

On the card shown in Fig. 1, it is evident that the line AB represents to some scale the varying pressure on one side of the piston during one stroke, while the line BD represents to the same scale the back pressure on the *same side of the piston during* the following stroke, and not, as is so conveniently assumed, the back presssure on the opposite side of the piston during the same stroke. In other words, the back pressure that is retarding the piston, while the pressure represented by the line AB is impelling it forward, is represented by the back pressure line of another diagram taken from the other end of the cylinder during the same stroke that the line AB was drawn. From the fact that the upper line of the card should be used in conjunction with the lower line of another card taken from the other end of the cylinder during the same stroke, it follows that two diagrams shown on the same card should never be paired, as it is impossible for one indicator to take diagrams simultaneously from each end. Two indicators, one on each end of the cylinder, are necessary for taking cards from which the mean effective pressure is to be *accurately* calculated.

In the actual running of an engine, however, there is usually so slight a variation from revolution to revolution, in the load and other conditions, that for all practical purposes a diagram taken from one end of the cylinder during any stroke may be paired with a diagram taken from the other end of the cylinder during an immediately succeeding stroke.

That it is possible to have a diagram with a very large area, and yet comparatively a very small mean effective pressure, will be made evident by a careful study of the diagrams shown in Figs. 1 and 2.

These diagrams may be regarded as simultaneously taken from the head-end and crank-end of a simple non-condensing engine. Fig. 1 may be regarded as the head-end card and Fig. 2 as the crank-end card.

The average length of the ordinates of the line AB above the atmospheric

line $O X$ is found by measurement to be 1 inch, and with an 80-lb. indicator spring, the mean pressure tending to move the piston toward the crank-end of the cylinder is 80 lb. $\times\ 1 = 80$ lb.

Opposed to this movement of the piston is a varying pressure acting on the other side of the piston. This is the back pressure, and its varying amount is graphically registered by the lower line $C'\ D'$ in the diagram in Fig. 2.

The average ordinate of the line $C'\ D'$ above the atmospheric line $O'\ X'$ is found by measurement to be $\frac{7}{16}$ of an inch, and this length with an 80-lb. spring gives $80 \times \frac{7}{16} = 35$ lb. for the back pressure.

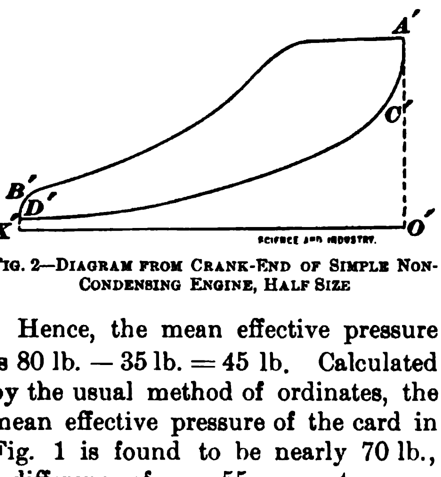


FIG. 2—DIAGRAM FROM CRANK-END OF SIMPLE NON-CONDENSING ENGINE, HALF SIZE

Hence, the mean effective pressure is 80 lb. $-$ 35 lb. $=$ 45 lb. Calculated by the usual method of ordinates, the mean effective pressure of the card in Fig. 1 is found to be nearly 70 lb., a difference of over 55 per cent.

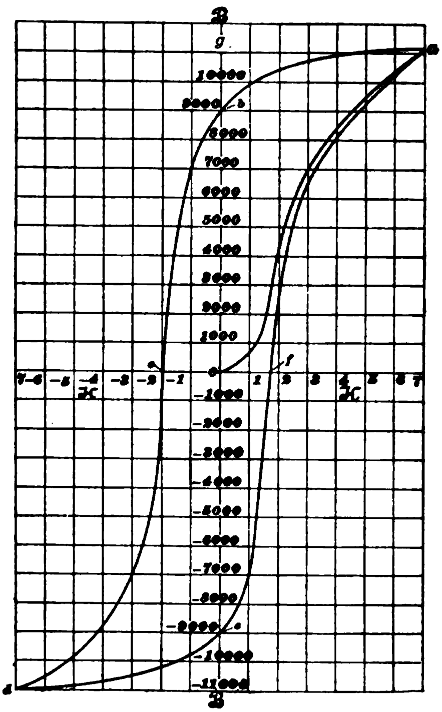
The area of the crank-end diagram shown in Fig. 2 is reduced by a cramped exhaust, but the mean effective pressure of the card may be shown to be much greater than the card would give, when subjected to the usual methods of computation. The average ordinate of the line $A'\ B'$, Fig. 2, above the atmospheric line $O'\ X'$ is found to be $1\frac{1}{32}$ inches, and this, with an 80-lb. spring gives a mean pressure above the atmosphere of 80 lb. $\times\ 1\frac{1}{32} = 82\frac{1}{2}$ lb. acting on the crank side of the piston. This is opposed by a back pressure, the variations of which are graphically registered by the lower line $B\ D$ of the head-end diagram shown in Fig. 1. The average ordinate of this back-pressure line is found by measurement to be $\frac{5}{32}$ inches, and this gives with an 80-lb. spring an average back pressure of 80 lb. $\times\ \frac{5}{32} = 12\frac{1}{2}$ lb. Therefore, the mean effective pressure of the stroke is $82\frac{1}{2}$ lb. $-\ 12\frac{1}{2}$ lb. $= 70$ lb. The usual methods give only 45 lb. as the mean effective pressure for the stroke, an error of nearly 36 per cent. In one case the mean effective pressure of the stroke is found to be much less than the area of the card would indicate, and in the other case, the mean effective pressure is found to be greater than that given by the usual methods.

It may be shown that these two errors just balance each other, and that when two cards, simultaneously taken, are considered, the usual method of computation will give correct results, because in the summation of the mean effective pressure of the cards, it makes no difference in the final result whether the back pressure of the cards was taken from the mean pressure of the card on which it appears or from the other diagram. The assumption that the back pressure of a stroke appears on the same diagram as the pressure producing that stroke is very convenient, as transferring the back-pressure line from one card to another would be a very tedious operation.

ELEMENTARY PRINCIPLES OF ELECTROMAGNETS—II

Hysteresis

If a piece of iron is perfectly neutral, that is, contains no residual magnetism whatever, and it is magnetized by a current flowing in a coil surrounding it, the magnetism, or magnetic density B, will increase as the magnetizing current, and hence the magnetizing force H increases as the current increases. The curve $O\,A$, in the accompanying figure, shows how B increases as H is increased. If, when the



Curve Showing Relation Between Magnetic Density and Magnetizing Force

magnetizing force H reaches its maximum value a it is gradually decreased to zero, that is, the current is decreased to a very small value and then the circuit opened, the magnetic density B will decrease along the line $a\,b$. It should be noticed at this point that although $H = O$, B has a value of about 9,000 lines per square centimeter. This represents the residual magnetism after the iron has been magnetized to a maximum density of about 11,100 lines per square centimeter and the magnetizing force then removed. If, now, the current is started and increased gradually in the reverse direction, the magnetizing force being thereby also reversed in direction, the magnetism will first decrease from B where it is $+9{,}000$ to c, where it is O. At this point $c\,H$ has a negative value of about -2. At this point the iron possesses no magnetism in spite of the fact that a magnetizing force of -2 is acting upon it. This reverse magnetizing force that is necessary to completely demagnetize a piece of iron is called its *coercive* force.

If the magnetizing force is increased in the negative direction until its strength is equal to its previous maximum positive value the flux density will increase in a negative direction along the curve $c\,d$ until its maximum negative magnetic density is about the same as its previous maximum positive value.

If, now, the magnetizing force is decreased from its value at d to zero, the magnetic density will decrease to a value $O\,e$ and if the magnetizing force is reversed in direction and increased to a value $O\,f$, the magnetic density will be reduced to zero. If the magnetizing force is further increased to its first maximum value, that is, to a, the magnetic density will increase to about its first maximum value in the positive direction. When a magnetic substance is magnetized so as to carry its magnetic flux through all the values represented by the curve *f–a–b–c–d–e–f* it is said to have been carried through one complete

cycle of magnetization. One cycle is made by two reversals of magnetism. For example, reversing the magnetism 40 times in one second will make 20 cycles in one second.

Now, it requires the expenditure of a certain amount of work in the magnetizing coil to increase the magnetization of the iron from f to a. This work is proportional to the area enclosed by the lines $f\,a$, $a\,g$, $g\,o$, and $o\,f$. But when the magnetization decreases from a to b the iron restores to the magnetizing coil an amount of this work proportional to the area enclosed by $b\,a$, $a\,g$, $g\,b$. The difference, which is proportional to the area enclosed by the lines $f\,a$, $a\,b$, $b\,o$, and $o\,f$, is not restored to the coil, but is transformed into heat and is lost in heating the iron. Evidently, the total energy lost in one complete cycle is proportional to the area enclosed by the complete hysteresis loop *d–e–f–a–b–c–d*. The heating of the iron is apparently due to a sort of inter-molecular friction.

The energy so dissipated in heat cannot be entirely avoided, but it may be reduced to a certain extent by making the cores of magnets, which are to be excited by alternating currents, of a quality of iron that shows by actual test only a small loss due to hysteresis. The hysteresis loss in ergs per cubic centimeter of iron for one complete cycle of magnetization is equal to the area in square centimeters enclosed by one hysteresis loop divided by $4\,\pi$. Of course, the curves would have to be drawn accurately to a centimeter scale and the area measured preferably by means of a planimeter in order to determine in this manner the energy so lost. However, there are other more practical methods for determining the loss due to hysteresis which cannot well be explained here.

The hysteresis loop shown in the figure is from a test on very soft iron. In other varieties or specimens of iron or other magnetic material the loop may enclose a larger or smaller area; but in every case there will be a loop, and the descending curve $a\,b\,c\,d$ will never be quite the same as that of the ascending curve $d\,e\,f\,a$, nor will either curve $f\,a$ or $a\,b\,c$ exactly agree with the original magnetizing curve $o\,a$. In designing electromagnets, the value of H, B, and u are always taken from the curve $o\,a$, the loop being only employed to determine the hysteresis loss.

It has been determined by a large number of tests, originally made by Mr. C. P. Steinmetz, but later by a number of persons, that the hysteresis loss, at the densities generally used in practical designing, is proportional to B^x. Steinmetz found the value of x to be 1.61, but later determinations seem to indicate that 1.5 is more nearly correct. The hysteresis loss may then be calculated by the formula $W = n\,B^{1.5}$; in which W is the work in ergs per cubic centimeter of iron per cycle, B the flux density per square centimeter, and n a constant depending upon the magnetic quality of the iron. A fair mean value for n for good annealed sheet iron or steel is .0033, for grey cast iron .013, and for cast steel .003.

USEFUL FORMULAS—VI

JOSEPH E. LEWIS, S. B.

SHAFTING, $H.P. = \frac{D^3 R}{C}$

IN this paper we shall deal with the strength and transmissive power of shafting. The material most commonly used at the present day is mild steel, although it was not very long ago that wrought-iron shafting was used, and before that cast iron and even wood were employed.

Cast iron is not a very satisfactory material on account of its brittleness, and it is not hard to understand how wrought iron came to supplant it. This latter material was for many years the principal material from which shafting was made. With the advent of steel, however, and the development of the Bessemer and open-hearth processes, wrought iron began to be supplanted for almost every purpose for which it was formerly used. The change has been gradual. Take the case of the steam boiler; formerly made of wrought-iron plates, they gradually came to be made of mild steel and then of a higher grade of steel having a higher percentage of carbon, until now, instead of wrought iron with a tensile strength of 45,000 pounds, we are using steel with a tensile strength of 65,000 pounds.

What is true in regard to boilers is also true in regard to shafting, although here there seems to be a greater reluctance to make the change owing to the impression so deeply rooted in the minds of many that steel is more brittle than wrought iron. This view has been quite widespread, and has found supporting evidence in the occasional breaking of large steel propeller shafts. Accidents of this sort were more common formerly than they are now, because the art of forging these shafts was not so thoroughly understood as at present, and it has become pretty evident that the trouble was not with steel as a material but rather with the manner in which it was forged.

The trouble was that the hammers used in forging were too light, so that only a thin layer of metal on the outside of a large shaft was properly worked, the whole interior being unchanged. Now, in finishing the shaft, this outside casing of tough metal was partly and sometimes wholly turned off. It is not surprising that these shafts should have broken occasionally, and it is perhaps a greater wonder that they did not break oftener and with more disastrous results. Test specimens have been taken from broken propeller shafts which were forged under light hammers. Specimens taken from near the surface showed great toughness due to proper working of the metal, but those from the center showed almost none at all, the metal being unchanged from its crystalline formation in the original ingot.

Modern practice has, however, very largely overcome these defects, which have been so largely to blame for the ill repute in which steel forgings have been held in many quarters. Greater care is now taken in casting the ingots than formerly, and many defects, such as blowholes, piping, segregation, etc., are more or less completely avoided in the ingot, and therefore in the finished shaft. The product of the open-hearth furnace is found to give the best satisfaction, and has been generally adopted for making forgings. Large shafts are now forged under powerful

hydraulic presses instead of light hammers as formerly, and the result is that the metal is properly worked at the center as well as at the outside of the shaft, so that the strength and toughness of the metal is uniform through and through.

Very large shafts are now made hollow. This may be accomplished in two ways. The shaft may be forged solid and bored out, or it may be forged hollow. This latter process consists in boring out the ingot and then forging it on a steel mandrel. Shafts 3 feet in diameter have been forged in this way.

Enough has been said to show why there has been a prejudice against steel shafting, and at the same time to make it clear that there is no longer reason for the existence of this prejudice. Steel has now almost entirely replaced wrought iron for all purposes, and wrought-iron shafting is practically a thing of the past.

Now let us turn to the formula for computing the strength of shafting. It will be remembered that work is force measured in pounds exerted through space measured in feet, so that the unit of work is a foot-pound or a pound lifted a foot against the force of gravity. The total work in foot-pounds is found by multiplying the force in pounds by the space in feet, and the horsepower exerted is found by dividing the total work done per minute by 33,000. Let us apply this to a shaft. Imagine a pulley 3 feet in diameter driven by a belt at a speed of 125 revolutions per minute. Suppose the pull on the belt to be 2,000 pounds, the pulley driving a shaft of suitable size. Let us compute the work done. Apply an old formula: work = force × space. In this case the force is 2,000 pounds. The pulley is 3 feet in diameter and therefore 9.426 feet in circumference. Then the space traveled by the rim in a minute is $125 \times 9.426 = 1,178\frac{1}{4}$ feet. Therefore, the work $= 2,000 \times 1,178\frac{1}{4} = 2,356,500$ foot-pounds,

or $$\frac{2,356,500}{33,000} = 71.4 \text{ H. P.}$$

Now the pulley tends to twist the shaft off at a cross section, but the shaft is strong enough to resist this twisting tendency between the driving pulley and the driven pulley. That is to say, instead of twisting off, the shaft turns, carrying around the pulleys and doing work. But it is subjected to a strain which we can measure. This strain acts upon a cross-section. That is to say, in Fig. 1, if we imagine the shaft cut in two at *C*, Part *A* will drive Part *B* pro-

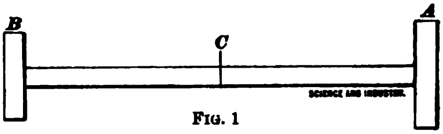


FIG. 1

vided some kind of a joint is made at *C*, and the strain will come at this point. Instead of cutting the shaft at *C*, just imagine that that part of the shaft at the right of the plane *C* is driving that part of the shaft at the left of the plane *C*. Now the metal has a certain strength per square inch of area on the plane *C*. This we will call its shearing strength, and we will represent it by f. That is, if we say $f = 60,000$ pounds, we mean that when the stress at the plane *C* exerted by *A* upon *B* equals 60,000 pounds per square inch, the shaft will twist off and break. Let the diameter of the shaft in inches be D, then $\pi \frac{D^2}{4}$ = the sectional area in square inches on the plane *C*. Then f multiplied by $\pi \frac{D^2}{4}$ or $\pi f \frac{D^2}{4}$ = the total shearing force which operates as a twisting stress upon the shaft. Now, this force distributed uniformly over the sectional area of the shaft produces the same effect as if the total

force acted at one point half way between the center and the circumference; that is, at a distance of $\frac{D}{4}$ from the center. Then we have, as before, a force operating through a space. The force is $\pi f \frac{D^2}{4}$, and the space is $\pi \frac{D\,R}{2 \times 12}$. It may not be quite clear where the expression $\pi \frac{D\,R}{2 \times 12}$ comes from. D is

Transposing, we have,

$$\text{H. P.} = \frac{\pi^2 f D^3 R}{96 \times 33{,}000}$$

in which $\frac{\pi^2 f}{96 \times 33{,}000}$ may be put equal to $\frac{1}{C}$, whose value will depend upon f. That is to say for shafting, H. P. $= \frac{D^3 R}{C}$ where C is a constant depending upon f.

Transmitting Power, but Subject to No Bending Action Except Its Own Weight							Transmitting Power, and Subject to Bending Action of Pulleys, Belting, Etc.					
Diameter of Shaft in Inches	Revolutions per Minute					Maximum Distance in Feet Between Bearings	Revolutions per Minute					Maximum Distance in Feet Between Bearings
	100 H. P.	150 H. P.	200 H. P.	250 H. P.	300 H. P.		100 H. P.	150 H. P.	200 H. P.	250 H. P.	300 H. P.	
1½	7	10	14	17	20	11.7	5	7	10	12	14	6.8
1⅝	9	13	17	21	26	12.4	6	9	12	15	18	7.2
1¾	11	16	21	26	32	13.0	8	11	15	18	22	7.5
1⅞	13	20	26	33	40	13.6	9	14	19	23	28	7.9
2	16	24	32	40	48	14.2	11	17	23	28	34	8.2
2⅛	19	29	38	48	58	14.8	14	21	27	34	42	8.6
2¼	23	34	46	57	68	15.4	16	24	33	41	48	8.9
2⅜	27	40	54	67	80	16.0	19	29	38	48	58	9.2
2½	31	47	63	78	94	16.5	22	33	45	55	66	9.6
2¾	42	62	83	102	124	17.6	24	36	48	60	72	10.2
3	54	81	108	134	162	18.6	39	58	77	96	116	10.8
3¼	69	103	137	172	206	19.7	49	74	98	123	148	11.4
3½	86	129	172	215	258	20.7	61	92	123	153	184	12.0
3¾	105	158	211	264	313	21.6	75	113	151	188	226	12.5
4	128	192	256	320	384	22.6	91	137	183	228	274	13.1

WORKING PROPORTIONS FOR SHAFTING OF MEDIUM STEEL
Taken from The Engineers' Handbook, published by the Pencoyd Iron Works

the diameter of shaft in inches, $\frac{D}{4}$ is the distance from the center of the shaft to the point at which the force acts. This point moves in a circle whose diameter is $\frac{D}{2}$ and whose circumference is $\pi \frac{D}{2}$. This multiplied by R, the number of revolutions per minute, gives the space in inches, and divided by 12 gives the space in feet.

Therefore, the work done is

$$\pi^2 f \frac{D^3 R}{96} = 2{,}356{,}500 \text{ foot-pounds.}$$

$$\pi^2 f \frac{D^3 R}{96} = 33{,}000 \times \text{H. P.}$$

Prof. Schwamb, in his Notes on Machine Design, gives the following values for C. For shafts subjected to some bending and line shafts with pulleys:

$$\text{Wrought iron, H. P.} = \frac{D^3 R}{100}; \quad (1)$$

$$\text{Mild steel, H. P.} = \frac{D^3 R}{83}. \quad (2)$$

For shafts used for transmitting power only and subjected only to bending due to their weights:

$$\text{Wrought iron, H. P.} = \frac{D^3 R}{50}; \quad (3)$$

$$\text{Mild steel, H. P.} = \frac{D^3 R}{42}. \quad (4)$$

These formulas may be transposed as follows, so that the required diameter of shaft may be computed from the horsepower and revolutions per minute:

$$D = \sqrt[3]{\frac{100 \text{ H. P.}}{R}}; \qquad (1)$$

$$D = \sqrt[3]{\frac{83 \text{ H. P.}}{R}}; \qquad (2)$$

$$D = \sqrt[3]{\frac{50 \text{ H. P.}}{R}}; \qquad (3)$$

$$D = \sqrt[3]{\frac{42 \text{ H. P.}}{R}}. \qquad (4)$$

STEAM TURBINES

WILLIAM BURLINGHAM

IT is evident that, with our present knowledge and experience of the difficulties with frictionless bearing metal, high-pressure steam packing, lubrication, and the various other minor constructional details that bar our further advance in practical steam engineering, we must look to some other method of utilizing the high-pressure and superheated steam that the latest types of water-tube boilers have rendered possible. Different from a few years ago, when the boiler pressure was the one desirable thing, we are now searching for a type of engine that will be capable of utilizing the high-pressure steam of the past few years.

The boilers are well on the road. As practical steam makers they are safe, efficient, and in most cases durable. The fireman, is of necessity a higher-class man than the old 30-pound coal pushers, and is easily trained to care for them. We may safely conclude that we have not yet reached our limit in furnishing pressures of many pounds above those now in use—that is, if we could utilize them. Even at this date there are many debates regarding the comparative merits of the compound, triple, and quadruple engine, yet it is probable that we have nearly if not quite reached the limit of efficiency as regards the reciprocating engine. We have juggled with expansion in one and many cylinders, jacketed and unjacketed, and our results vary little one from the other. The piston speed, with the use of our present materials of engineering, has about reached its maximum. Our rod stuffingbox packings melt or leak under the heat of high-pressure steam. Our engines are unbalanced at the high number of revolutions, or are so light in construction that they are liable to go to pieces at the least trouble, and our engineers are earning gray hairs early in life.

It is not my intention to criticise the present designs of steam motors, but to suggest that we look into a radically different type of machine in which piston speed or rod packing is not a factor. The present reciprocating-engine design is the result of years of experience and is probably the best possible for that type, and its essential design will probably remain unchanged as long as a reciprocating engine is used. All this means that we need a new type, different in all particulars from the old or present one.

The first hint of the real necessity for a high-speed revolving motor came into being with the commercial development of the dynamo. It was very desirable to run the dynamo coupled directly with the engine, but notwithstanding the attempts of the past few years, it has not yet been accomplished in its entirety with reciprocating engines. The belting of the dynamo to the engine is a crude mechanical method of driving, taking up a great deal of

room, but to obtain a minimum first cost of the dynamo this has been necessary.

The load capacity of an electric generator is directly proportional to its speed, and this speed must be made as high as mechanical considerations will admit. A reduction in the peripheral speed is coincident with a corresponding increase in the weight and cost per kilowatt of the generator, and is perhaps a cause of a reduction in its efficiency. In the case of alternators, a low peripheral speed causes great crowding of the poles, prevents a proper distribution of the armature windings, increases self-induction, and injures regulation.

The second cause of the building of high-speed revolving motors was the demand for fast torpedo boats and destroyers. In this type of boat the reciprocating engine has been carried to its highest state of efficiency, yet even thus it is but a year or so ago that all records were broken by a motor of different type that was only a few years past its inception.

In a torpedo-boat engine, vibration is unusually excessive, and although many schemes have been tried more or less successfully to counteract this, the problem is still unsolved.

A torpedo-boat engine must be economical in coal, as there is but little coal-bunker space. It must weigh but a few pounds per horsepower, which means unduly light working parts. It must be as simple as possible in design to avoid danger of getting out of order, and it should be durable.

It is a very difficult matter to combine the various solutions of these problems in one boat, and it has not yet been done.

The most promising solution of the problem is in the use of the steam turbine, invented by Mr. Charles A. Parsons, of Newcastle-on-Tyne. I quote from Prof. Robert H. Thurston on the advantages of this motor in marine work:

1. Increased speed.
2. Increased economy of steam.
3. Increased carrying capacity of vessel.
4. Increased facility for navigating shallow waters.
5. Increased stability of vessel.
6. Increased safety of machinery for war purposes.
7. Reduced weight of machinery.
8. Reduced space occupied by machinery.
9. Reduced initial cost.
10. Reduced cost of attendance on machinery.
11. Diminished cost of up-keep of machinery.
12. Largely reduced vibration.
13. Reduced size and weight of screw propellors and shafting.

These statements are a little early to be absolutely positive, as we are yet to prove that the qualities of a theoretical turbine are those of an actual working turbine a few years old.

The turbine, as built, has not yet attained all the advantages that are coming to it in the future, but enough has been done to cause us to anticipate more from it.

The steam turbine is so often spoken of and its method of working is so little known that it is about time to spread its modus operandi abroad that our mechanics and inventors may have their attention attracted toward it. There are two types of steam turbines on the market at present, the DeLaval and Parsons. They are both being developed in this country, the Parsons in particular by the Westinghouse Machine Co.

The two types are similar in this respect—they accomplish the transla-

tion of energy by a free expansion of the steam; that is, there is no piston to offer a yielding resistance, and the work is done by the expansion imparting a velocity to the mass of the steam itself. This kinetic energy of the steam or gas is transformed into mechanical power at the shaft by the striking of the molecules of the steam upon blades or vanes set in the shaft drum, in a similar manner to the action of the water upon the buckets of an impulse wheel.

In waterwheels, the linear velocity of the buckets must be one-half that of the speed of the water projected thereupon to obtain a satisfactory efficiency, and for this reason the attainment of a high economy in a steam turbine has been, and is now, very difficult. The weight of a unit of steam is so small as compared with the energy developed by it in expanding from boiler pressure to vacuum that its velocity is something like 120,000 feet per minute, more or less, depending upon the number of expansions. The difficulty of obtaining machines whose peripheral speed approaches one-half this is very evident. In the DeLaval type of turbine the expansion is done in a large trumpet-shaped nozzle, that is, one with diverging sides. As the steam passes through this nozzle, its specific volume is increased in greater proportion than the area of the tube, thus increasing its velocity and momentum until the end of expansion at the last sectional area of the tube or nozzle. The greater the expansion in the nozzle, the greater its velocity leaving the nozzle.

The speed of the steam is so high that no mechanically constructed machine can hold together at the tremendous number of revolutions necessary to attain efficiency. Gearing down, the method adopted in the DeLaval turbine to reduce the revolutions to a practical number, is not considered a good practical method for driving. It is possible, however, to use the turbines in series; that is, the exhaust of one machine discharging into the inlet of the next. In one of the DeLaval turbines the speed is 30,000 revolutions per minute reduced to 3,000 by gearing provided with special cogs.

In the Parsons type of machine the expansion is obtained after the steam has entered the machine; that is, through the runner and guide blades through which the steam passes in succession. After entering the space between the blades on the shaft and impinging thereon, the steam flows through the next set of guide blades and is deflected therefrom to the next set of runner blades, each set of runner and guide blades being of larger cross-section to allow for the diminution in the energy of the steam, thus making the work of each set of blades the same. This arrangement of blades, etc. is enclosed in a casing something like the stepped pulley cone of a lathe.

Through these means the revolutions are brought down within practical limits for dynamo work, although up to the present date it is too great for marine work, for the slowest turbine has a much higher number of revolutions than the best reciprocating engine.

The following is a detailed description of the working of a Parsons turbine:

There is an annular chamber surrounding the shaft into which the steam is admitted at boiler pressure. It then flows parallel to the shaft through a series of rings of vanes and guide blades, expanding gradually from ring to ring until it reaches a large chamber, thence to the condenser. Fig. 1 shows, roughly, a sketch of the vanes and guide blades. The slots *A A A*, which are fixed in the casing,

are so inclined that the steam flow is given a right-handed rotation around the shaft. The vanes forming slots *B B B* are curved in the opposite direction; thus, when the steam coming through slots *A A A* strikes the curved surface of *B B B* with its right-handed rotation, it rebounds and is given a left-handed rotation, passing into the next ring of fixed slots. As the steam flows between these vanes from left to right, the stationary ones give it a right-handed rotation, in a circle of which the curvature of the vane is a part of the circumference; this throws it into the hollow of the moving vanes from the surfaces of which it is thrown back into the belly of the vanes of the next stationary row, and so on until it flows into the exhaust chamber. The stationary vanes are given a backward thrust by the steam, but they resist this, and the forward thrust to the movable vanes is tangential to their circular path, this forward thrust giving the power to the turbine. As the steam passes through the series of rows, the blades increase in size, mostly radially, giving the opportunity for expansion; thus, the power given up to the first ring of blades is made up for the second by the expansion before reaching the next ring of blades. In this way the turbine acts as a multiple expansion engine.

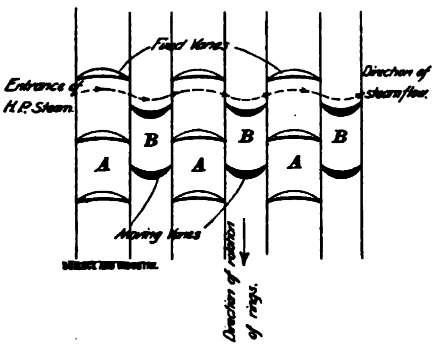


FIG. 1—VANES AND GUIDE BLADES OF THE PARSONS TURBINE

Prof. Thurston makes the following statements, which are here somewhat abridged:

1. The steam turbine thermodynamically approximates very closely to the ideal heat motor.

2. It is entirely free from steam waste, a great loss in all other types.

3. It is the ideal type for use with high-pressure steam.

4. It is limited in rotative speed by the strength of the materials of construction only.

5. It allows of the use of superheated steam, as there are no rubbing parts needing oil.

6. The wastes of the turbine are all outside of the steam lines and are: first, journal friction; second, fluid friction between disc and enclosing vapor; third, leakage; fourth, incomplete expansion; fifth, a certain thermodynamical waste, which we will not go into, as other advantages so counterbalance this that we can eliminate it. Its disadvantages in marine work are lack of reversibility and loss of efficiency at low speeds. Their excessive cost is also a hindrance at present.

In the usual type of turbine the casing containing the motor is enlarged in three steps, but the cross-sectional area of the passages between the vanes is increased many times, in many small steps giving a gradual expansion of steam. In a plant located at the works of the Westinghouse Air Brake Company, consisting of three 500-horsepower turbines running at 3,600 revolutions per minute, the expansion ratio between inlet and outlet is 96 to 1 and the number of vanes on the rotating barrel is 58. The weight of the complete turbine and generator is 25,000 pounds, that is, 50 pounds per horsepower.

Some of the mechanical difficulties

connected with the fitting and running of these machines are as follows:

1. Counteracting the end thrust, due to axial impact of the steam on the moving blades.

2. Securing a complete balancing of the rotating portion of the machine.

3. The lubrication of these rapidly revolving shafts.

4. Governing or regulating the speed of the machine when the load is changed or entirely thrown off.

Mr. Parsons, in his patent papers, describes the operation of his motor as follows:

"Now, according to my invention, to obtain a low effluent or terminal pressure while using a comparatively high initial pressure, I use a compound motor or combination of motors so arranged that the same actuating fluid operates therein in a successive manner, undergoing expansion and falling in pressure in each until it leaves the last at a velocity not greatly above that which is practically attainable by the motor itself. By this arrangement each motor or successive portion of the compound motor utilizes a portion of the energy of the fluid, and thus, instead of the greater part being wasted as heretofore, it is successively drawn upon until a comparatively high efficiency is obtained."

Here is the essential difference between the DeLaval type of turbine and the Parsons, it being mechanically possible to make the peripheral speed of the Parsons turbine nearer the terminal speed of the steam than it is in the DeLaval.

In Fig. 2 we can trace the method of operation as follows:

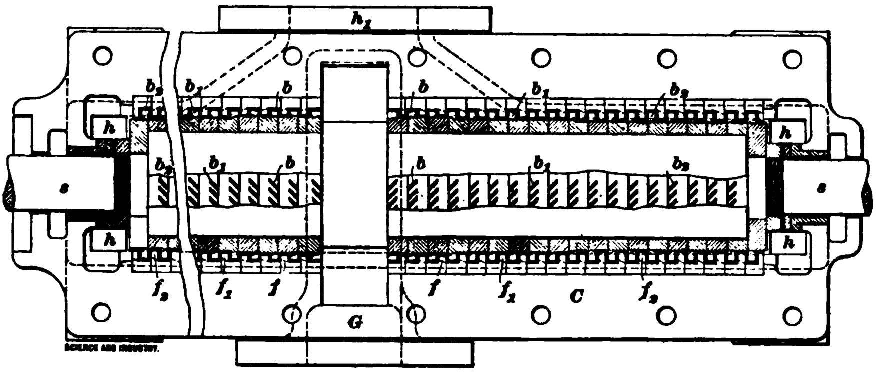


Fig. 2—Sectional View of Parsons Turbine

Steam enters the motor at its center *G* and travels toward each end of the motor between the respective moving cylinders and fixed casing *C*, acting in its passage upon the blades $b\,b_1\,b_2$, $b\,b_1\,b_2$, and being deflected and guided by the fixed blades $f\,f_1\,f_2$, $f\,f_1\,f_2$, until it reaches the exhaust passages $h\,h$, which are carried underneath the motor to the center, the exhaust branch h_1 being at the opposite side of the motor to the supply branch. It will be seen upon examining the blades $b\,b_1\,b_2$ that where the steam enters they are comparatively shallow, but towards the respective ends of the motor they increase in depths by sets, b_1 being deeper than b, and b_2 than b_1. It will also be seen, upon reference to the drawings, that where the steam enters, the blades are set at a greater angle than where it

exhausts; hence, as the steam pressure decreases it meets with sets of blades of increased area and pitch, the increase being so calculated that the velocity of the steam shall be suitable to that set of blades between which it has to pass. By these means the gradations of pressure are governed. It will be understood that as the steam flows toward the respective ends of the motor, its action upon the blades $b\ b_1\ b_2$ will have the effect of imparting rapid rotary motion to the shaft s.

The high speed necessitates careful balancing of the rotating parts of the turbine, and, as it cannot be made absolutely perfect, the bearings are made with a slight play to allow the center of gravity of the rotating member to settle into the center of rotation. Fig. 3 gives the general idea of the plan. There is a light bush "i," outside of which are placed metal rings or washers $k\,k_1$. The alternate washers k are slightly larger in diameter than k_1, so that the alternate washers k fit the casing, but not the bush, and the washers k_1 fit the central bush, but not the casing. By the spring, these washers are pressed tightly together. The bush is now capable of a slight lateral movement, but this movement is resisted and controlled by the rings or washers and their mutual friction.

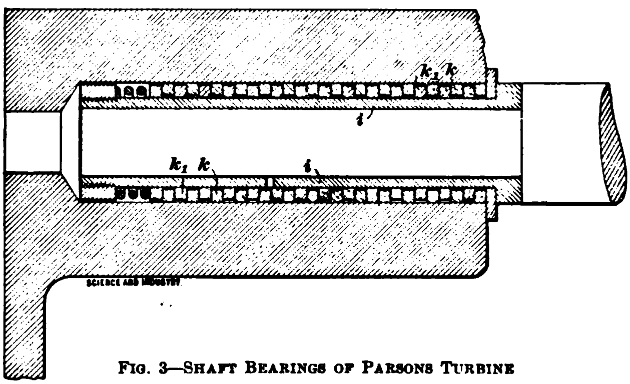


FIG. 3—SHAFT BEARINGS OF PARSONS TURBINE

The method of governing these turbines is novel; as the passages through the blades cannot be shut off, it would seem that the most obvious and only way of governing was by throttling. But, in this turbine an ordinary ball governor is used to actuate a small piston, which, in turn, admits steam to a large piston, which opens or shuts the main throttle valve. If the turbine increases its revolutions, the governor balls fly out, closing the valve, and vice versa, admitting the steam into the turbine in gusts. At full load the main valve is open most of the time, and at light loads it is closed most of the time. At intermediate loads it is intermittently opened and closed more or less rapidly as the load is changed.

Since the original design, the structure of the motors has been much improved, but the general principle of operation is that stated in this article. Originally the vanes were milled from solid rings of cast brass or delta metal, but experience proved that hidden flaws sometimes existed, causing fracture of a vane and consequent extensive damage to the turbine. At present, wrought blades of special brass are used, curved to shape and keyed into dove-tailed grooves in the case and drum, shown in Fig. 4. This arrangement gives a very smooth surface and a material absolutely trustworthy.

The performance of these turbines is showing up well, Professor Erving's trials of a torpedo-boat engine giving a consumption of about 14½ pounds of steam per horsepower at a boat speed of 32 knots per hour.

The weight of turbines, shafting, and

propellers for a boat is calculated at one-half that of the ordinary screw engine, shafting, and propellers, while it is less than one-third that of a paddle wheel engine. A steamer built by Messrs. W. Denny & Bros., 250 feet long, 30 feet beam, is engined by three separate turbines driving three screw shafts. The high-pressure turbine is placed on the center shaft, and the two low-pressure turbines drive the outer shafts.

There are two astern turbines in the exhaust ends of the low-pressure turbines. The operation is as follows:

The steam from the boilers is admitted to the high-pressure turbine, in which it is expanded about 5 fold, then to the low-pressure turbine, where it is expanded about another 25 fold, and then to the condensers. The total ratio of expansion is about 125 fold as compared with the 8 or 16 fold of the ordinary triple reciprocating engine. At 20 knots speed, the number of revolutions of the center shaft is 700 and of the two outer ones 1,000 per minute.

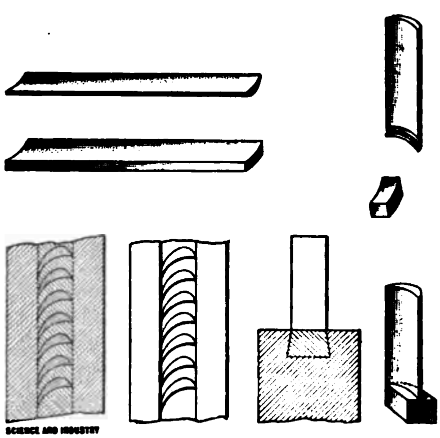


FIG. 4—SHAPE OF VANES AND BLADES USED IN PARSONS TURBINE

The boilers are of the usual double-ended Scotch pattern.

The following facts regarding some turbine vessels built by Messrs. W. Denny & Bros. is taken from the Marine Review: "If the King Edward had been fitted with balanced twin triple-expansion engines of the most improved type, and of such size as would consume all the steam the existing boiler could make, her displacement would have been slightly increased to carry the extra weight of triple engines as compared with turbines. Under these conditions the best speed they could possibly have got would have been 19.7 knots, against 20½ knots actually done by the King Edward. Thus, the increase of speed was eight-tenths of a knot per hour. Two-tenths of this was due to the lesser displacement in the King Edward as a turbine steamer, and six-tenths was due to the superior effciency of the turbine engine and its accessories. The difference between 19.7 and 20.5 knots corresponds to a gain in indicated horsepower in favor of the turbine steamer of 20 per cent.; but it would hardly have been possible to drive the King Edward 20½ knots with ordinary engines at all, owing to the extra weight and the necessarily increased displacement. The attempt to do so could only have resulted in this speed being got at an enormously increased first cost and a ruinous expenditure of coal, etc. on service. As to coal consumption, the paddle-steamer Duchess of Hamilton and the King Edward results on service had been compared. From the comparison it had been found that the Duchess of Hamilton at 16½ knots burned 16 tons, and the King Edward at 18½ knots burned 18 tons. The Duchess of Hamilton, however, had only compound engines; by the use of triple engines her consumption could be reduced, but even with triple engines, if she were to be driven at 18½ knots on service, her consumption would have been over 22 tons as against 18 tons in the King Edward, which corresponded to a saving

of about 20 per cent. in favor of the latter. This is on the assumption that the Duchess of Hamilton was left as she was in displacement and draught, and that she could have carried machinery powerful enough to insure $18\frac{1}{2}$ knots on service, but as her speed on trial was only 18 knots, the greater displacement necessary to carry the increased weight of machinery for the higher speed would have resulted in a considerable increase in the coal consumption of 22 tons. It is known that turbine engines at a much lower power than that for which they are designed are not so economical in coal consumption as ordinary engines. Up to the highest speed at which the King Edward had been driven, an always increasingly favorable consumption of coal was found in relation to the speed of the vessel, but there is no means of knowing how far this tendency might reach. Her speed would have had to be reduced to between 17 and 18 knots, as on trial, before ordinary engines, under the same conditions and at the same speed, would burn less per knot of speed; this 17 or 18 knots speed corresponding to about 50 per cent. of the total maximum power of the turbine engines in the King Edward. The up-keep of the turbine engines for the season was very slight. As to cost, even including the royalties charged, turbines are not more expensive than other engines, and with more experience in their manufacture they will ultimately become considerably cheaper. If the Queen Alexandra turns out to be as successful as the King Edward was, it is almost certain there will be a very large application of turbine machinery."

The trial of a 500-kilowatt steam turbine connected to an alternating-current machine on January, 1901, after 12 months' use, gave the following results:

Compound turbine, 2,700 revolutions per minute. Steam, 150 pounds. Surface condenser.

Output in Kilowatts	Steam Consumption	
	Pounds per Hour	Pounds per Unit
600	14 600	24.3
500	12,500	25.0
400	10,400	26.0
300	8,300	27.7
200	6,140	30.7
100	4,020	40.2
75	3,550	47.7
50	2,840	56.8
0	1,850	

The efficiency is high, and, as can be seen, is well maintained even when the load is reduced to one-quarter or less of its normal amount.

In the test of another machine, the steam consumption from a 500-horsepower turbine set was as follows:

1 load 16.4 lb. of steam per electrical H. P. per hour
¾ " 17. " " " " " " " "
½ " 18.2 " " " " " " " "
¼ " 22. " " " " " " " "

Running light, 750 pounds of steam per hour.

The Cleveland, Elyria & Western Railway have contracted for two 1,500-horsepower Westinghouse-Parsons turbines, direct connected to two 1,000-kilowatt, 2-pole, 4,100-volt, 25-cycle Westinghouse generators. The Westinghouse Company guarantees that with 150-pounds steam pressure and 100° F. of superheat at throttle and 28" vacuum, that the steam consumption shall not exceed 10.08 pounds per I. H. P., and at one-half load shall not exceed 15 per cent. more than at full load.

In the space occupied by an installation of two 500-kilowatt alternating-current machines with ordinary engines, there is space sufficient to install two 1,000-kilowatt turbine generators, with enough space for a 2,000-kilowatt unit.

Another economy of this installation is the light foundations possible, as these turbine generators can be run on an ordinary board floor if necessary.

The turbine today is as yet in the course of development and it is hard to say what the final outcome will be. At high speeds there is no doubt but that it is by far the most economical engine extant. The question now is this: Is it possible to have an economical turbine at a lesser speed? It is too early to say "no" to this, and the future of the turbine as an engine for general land and marine work depends upon this *one* point.

A SMALL, EASILY-MADE TRANSFORMER

R B. WILLIAMSON

THE purpose of this article is to show how to build a small alternating-current transformer suitable for experimental work that does not require a large output. The con-

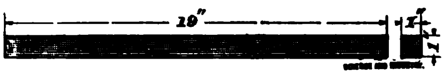


FIG. 1—SHOWING FORMATION OF LAMINATED-IRON CORE

struction is very simple, and there should be no difficulty in building the transformer, as the materials are such as can be easily obtained. We will describe simply the construction of the transformer itself, leaving the design of a suitable case for it to the reader.

The transformer is of approximately 100 watts capacity, and we will design it for transforming from 100 volts to 10 volts on 125 cycles; 10 volts secondary pressure is a convenient one for light experimental work, because, with the aid of a rheostat, pressures suitable for operating small lamps, etc., can be easily obtained; or, if desired, the secondary may be wound in sections, thus making a number of different voltages available.

The first part to be constructed is the laminated-iron core. In order to make this, secure at a tin shop a number of strips of black sheet iron 1 inch wide and 19 inches long. Get enough of these strips to build up to a thickness of 1 inch. The iron should be about .015 inch to .020 inch thick; the thinner the better, though there is little object in having it much thinner than .015 inch; 40 to 60 strips will be required. These strips should be bundled together and heated to a dull red heat for an hour, and then allowed to cool slowly. This anneals the iron and improves its magnetic qualities. The annealing is not absolutely necessary in a small transformer of this kind, and it may be omitted if means are not at hand for heating the iron conveniently, but it is advisable to do it if possible. Fig. 1 shows the dimensions of the core made by building up the strips.

After the strips have been annealed, build them up regularly together and clamp them tightly at the middle point in a vise, as shown in Fig. 2, and while held in the vise twist two pieces of copper wire around as shown at *a a*, placing these pieces about 6½ inches

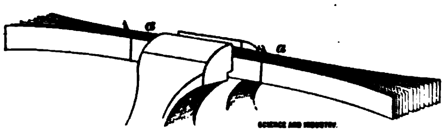


FIG. 2—METHOD OF HOLDING IRON STRIPS FOR FASTENING

apart. Now remove the strips from the vise and twist a third piece of wire around the bundle midway between

the first two. This will hold the strips closely together in the central part, as shown in Fig. 3. Next, begin wrapping the core with cotton tape ($\frac{1}{2}$ inch wide), beginning close up to one of the end copper wires. This tape should be half lapped, as shown in Fig. 3, and wound on tightly. When wound over

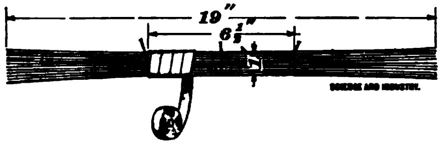


Fig. 3—Winding Core With Tape

to the center, the middle copper wire is removed, as the tape now helps to hold the strips in place. The tape is wound on over to the end and the layer is thoroughly soaked with shellac or other insulating varnish. The tape is then wound back to the starting point, and the end fastened there to the first layer; this layer is also thoroughly varnished. The core is now placed in an oven and baked for five or six hours, thus hardening the varnish on the tape; this tape will hold the core together, but it is just as well to leave the copper wires on the ends until after the winding is completed. This completes the core, and the next point is to determine the windings. Fig. 4 shows the completed core ready for winding.

The winding of the primary coil is determined from the formula,

$$\text{E. M. F.} = \frac{4.44 \times \text{magnetic flux} \times \text{number of turns} \times \text{frequency}}{100,000,000};$$

or,

$$\text{number of turns} = \frac{\text{E. M. F.} \times 100,000,000}{4.44 \times \text{magnetic flux} \times \text{frequency}}.$$

The frequency is usually known and in this case is 125. The magnetic flux must be taken with regard to the cross-section of the core. With a frequency as high as 125 cycles per second, it will not be advisable to use a magnetic density in the core much higher than 20,000 lines per square inch. Our core is 1 inch by 1 inch, and the cross-section of iron in it will be about 90 per cent. of the total cross-section, as there is always a slight space between the strips. We can count, therefore, on about .9 square inch, and the total magnetic flux through the core will be $20,000 \times .9 = 18,000$ lines. The primary E. M. F. is to be 100 volts; hence, we have,

$$\text{number of turns} = \frac{100 \times 100,000,000}{4.44 \times 18,000 \times 125}$$
$$= 1,000 \text{ turns, approximately.}$$

The next point is to decide upon the size of the primary wire. For an output of 100 watts, the primary current would, neglecting losses and magnetizing current, be $\frac{\text{watts}}{\text{volts}} = \frac{100}{100} = 1$ ampere. The wire in the coils should have a cross-section of about 1,000 circular mils per ampere in order to avoid overheating; hence, the cross-section of the primary wire should be about 1,000 circular mils. By consult-

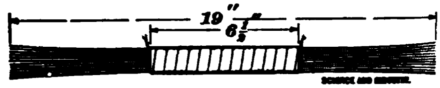


Fig. 4—Completed Core Ready for Winding

ing a wire table we find that a No. 20 B. & S. has a cross-section of 1,021 circular mils, so that we will use this size. The wire should be double cotton covered, and the diameter over the covering will be about .040 inch, and about 25 turns can be wound per inch length of core. The coil will be 6 inches long, so that each layer will

contain about 150 turns. The upper layers will be somewhat shorter than the lower ones, as shown in Fig. 5, and 7 layers will be required to accommodate the 1,000 turns. By making each successive layer a few turns shorter than the first, the ends are coned as shown and the wire stays in place.

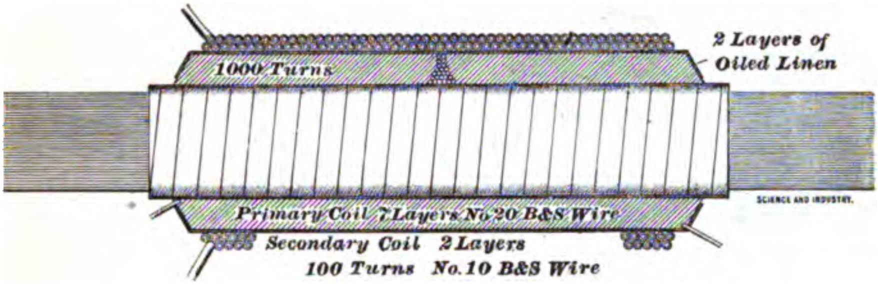


FIG. 5—CROSS-SECTION OF PRIMARY AND SECONDARY COILS

Before winding the primary in place, the taping on the core should be covered with a wrapping of two thicknesses of linen that has been given four coats of linseed oil, each coat being allowed to dry before the next is applied. This taping insulates the coil from the core. The binding tape first applied is not depended on for insulation; it helps in this respect but its primary object is to hold the core strips together. After the primary coil has been wound on, the temporary copper wires *e a*, Fig. 2, may be removed as they are no longer needed. As the coil is wound it should be thoroughly shellaced or coated with other insulating varnish, and then baked until it is thoroughly dried out.

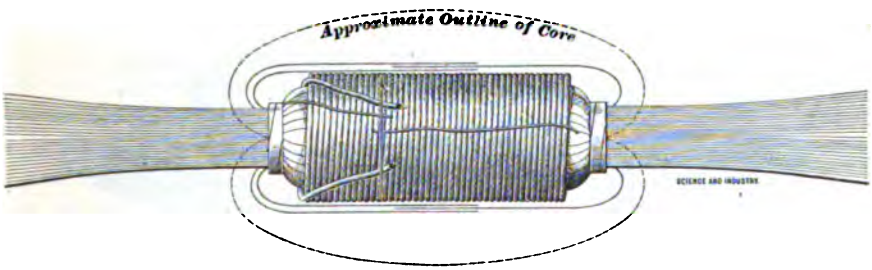


FIG. 6—SHOWING POSITION OF IRON STRIPS

The next part requiring attention is the secondary coil. The secondary voltage is to be 10 volts, the primary voltage is 1,000 volts. The secondary current of a transformer at full load is found close enough for the present purpose from the following:

$$\text{Secondary current} = \text{primary current} \times \frac{\text{primary voltage}}{\text{secondary voltage}}.$$

In this case, therefore,

$$\text{Secondary current} = 1 \times \frac{100}{10} = 10$$

amperes.

The number of secondary turns is found as follows:

$$\text{Secondary turns} = \text{primary turns} \times \frac{\text{secondary voltage}}{\text{primary voltage}}.$$

Hence, for this transformer,

$$\text{Secondary turns} = 1{,}000 \times \frac{10}{100} = 100.$$

The secondary coil must then be wound

with 100 turns of wire capable of carrying 10 amperes. Allowing 1,000 circular mils per ampere as before, the secondary wire should have a cross-section of 10,000 circular mils. A No. 10 B. & S. has this cross-section very nearly, and there will be no difficulty

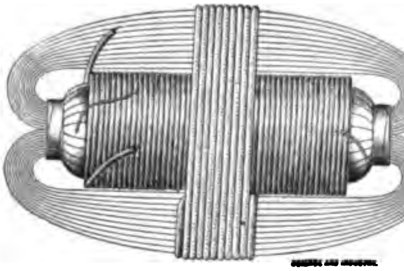


Fig. 7—Coils With Strips Bent Back

in placing the 100 turns in two layers of 50 turns in each. Before winding on the secondary, the primary should be covered with two layers of oiled linen so as to insulate the coils from each other. The ends of the coils should be securely fastened either by tying with strong twine or better by passing tape around them and under a number of the adjacent turns. After the secondary coil has been wound, shellaced, and baked, the ends of both coils should be bent back over the top temporarily and bound there. Fig. 5 shows a cross-section of the primary and secondary coils. Both coils are usually wound in the same direction, though this is immaterial.

The next step is to bend over the free ends of the iron strips so as to complete the magnetic circuit. Half the strips bend towards one side of the coil, and half towards the other at each end. Fig. 6 shows what is meant. As the strips are bent back they should be hammered at the bend or squeezed in a vise to make them lie in place. In doing this care must be taken not to bruise the coils in any way. The strips should be bent back one at a time, first at one end and then at the other, so that they will interleave. The first few strips that are bent back will overlap by quite a long distance, but the outer strips will barely meet on account of the longer radius of the bend at the ends. In fact, if care is not taken in bending the strips so as to make them lie close together, the last few strips will not meet, but this will make no perceptible difference in the operation of the transformer.

After the strips have been bent they should be bound together at the center by strong cord neatly wound on, as shown in Fig. 7, which represents the completed transformer.

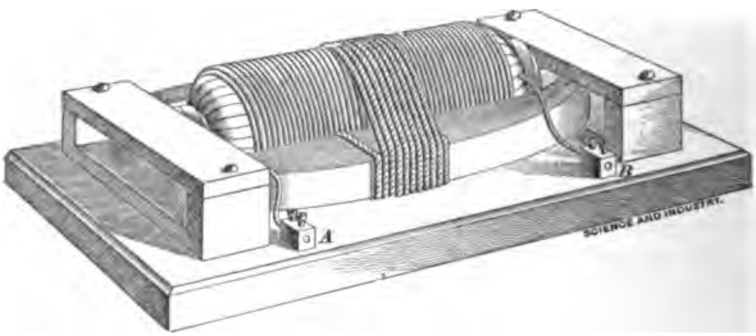


Fig. 8—Completed Transformer

The transformer may be mounted as shown in Fig. 8. *A* is one of the secondary terminals, and *B* one of the

primary. The other two are arranged similarly on the other side of the transformer. Any convenient style of binding post may be used for the terminals, but the plain brass blocks shown in the figure are substantial and answer as well as any. If a better finish is desired, the transformer may be mounted in a neatly finished box with the primary and secondary terminals on top. If a box is used, it should be ventilated by making a number of openings in the sides and ends, and covering these on the inside with brass gauze.

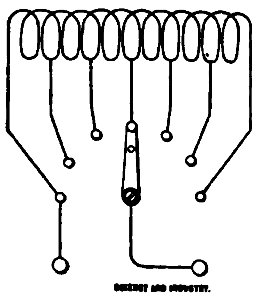


FIG. 9—METHOD OF OBTAINING DIFFERENT SECONDARY VOLTAGES

If it is desired to obtain a number of secondary voltages, taps may be brought out from the secondary coil, as shown in Fig. 9, and connected to a switch. If the taps are brought out every 10 turns, pressures from 1 volt to 10 volts can be obtained in steps of 1 volt. Bringing out these taps from the lower layers is a somewhat troublesome job, because the taps interfere with the upper layer of the winding. However, by using pieces of thin sheet copper, as shown in Fig. 10 (*a*), or pieces of flexible lamp cord, as shown in Fig. 10 (*b*), the taps can be made quite neatly.

If the transformer is operated on 60 cycles instead of 125, the effect will be to increase the magnetic density in the core to about double the value for which the core was originally designed. This will increase the heating somewhat, but if the iron is of good quality the heating will not be very large, because a low density, 20,000 lines per square inch, was assumed in the first place. The no-load current taken by the primary will also be increased, because a greater magnetizing force will be required to set up the magnetic flux. This will tend to increase the heating in the primary coil. The net result, therefore, of operating the transformer on 60 cycles would be to make it run somewhat warmer. The transformer should not, however, run very warm especially if it is used on an intermittent load as is usually the case in experimental work. The seconndary voltage would not be affected by a change in the frequency so long as the primary voltage and the ratio of primary to secondary turns are not altered.

If the primary is to be wound for 50 volts, and the secondary for 10 volts, use 500 turns of No. 17 B. & S. on the primary and the same winding as before on the secondary.

For a primary voltage of 100 and a secondary voltage of 5, use 1,000 turns of No. 20 for the primary and 50 turns of two No. 10 wires in parallel for the secondary. In this case the secondary current would be 20 amperes, so that twice the cross-section of copper required for the 10-volt secondary is necessary; this is easily obtained by winding two No. 10 wires in multiple,

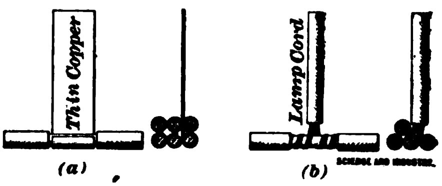


FIG. 10—METHODS OF BRINGING OUT TAPS FROM SECONDARY COILS

thus making the general dimensions of the secondary the same as shown in Fig. 5, the only difference being that the effective number of turns is one-half as great.

For a primary voltage of 50 and secondary voltage of 5, use 500 turns of No. 17 for the primary, and 50 turns of two No. 10 wires in multiple for the secondary.

This small transformer will be found useful for a number of purposes, especially if it is used in connection with a small rheostat by means of which the secondary current can be regulated. For operating miniature lamps, supplying current for operating small alternating-current motors, or in fact for any purpose where a small alternating current at low voltage is required, it will be found very convenient. It is specially handy for experiments illustrating the heating effects of the electric current; it will fuse a considerable length of No. 18 iron wire without difficulty. The transformer, with a 5-volt secondary and taps brought out every 5 turns, makes a good appliance for heating cautery knives used in surgical work. The 5-volt secondary, with taps every 5 turns, gives 10 steps of ½ volt each, which is a close enough adjustment for most work and allows the transformer to be used without any auxiliary rheostat.

SIMPLE MEASUREMENTS WITH VOLTMETERS AND AMMETERS

TO measure resistance by the use of a voltmeter, connect the voltmeter across the terminals of a constant potential circuit, noting the reading; then connect the unknown resistance in series with the voltmeter across the terminals, which will then give a lower reading than the first. Now the following formula may be used: Divide the first reading by the second reading, then multiply by the resistance of the voltmeter, then from the result subtract the resistance of the voltmeter, and the result obtained will be the ohms resistance of what is being measured. For example, suppose the first reading be 20 volts and the second after the resistance has been placed in series be only 10 volts, and the resistance of the voltmeter 1,000 ohms. Then $\frac{20}{10} \times 1{,}000 - 1{,}000 = 1{,}000$, which would be the resistance of that which is being measured.

To measure the amount of current flowing in a circuit by the use of a voltmeter, place a known resistance in the circuit and measure the difference of potential between its ends. The volts so indicated, divided by the known resistance, will give the number of amperes flowing. For example, suppose a known resistance of 5 ohms be placed in a circuit and the difference of potential between its two terminals is 20 volts, then the amount of current flowing in the circuit would be $20 \div 5 = 4$ amperes.

To measure resistance by an ammeter, place the ammeter in series with the circuit to which is applied a known voltage, then divide the voltage by the number of amperes indicated, which will give the resistance. For example, suppose a voltage of 100 and a current of 2 amperes, then the resistance must be $100 \div 2 = 50$ ohms.

To measure voltage by an ammeter, place a *comparatively high* known resistance in series with the ammeter and across the circuit, then the current so indicated multiplied by the known resistance will give the voltage of the circuit. For example, suppose a resistance of 10 ohms in series with an ammeter across a circuit and the current indicated be 3 amperes, then the voltage must be $10 \times 3 = 30$ volts.—Electricity.

COMBUSTION

OTTO LUHR

IN THE NATIONAL ENGINEER

COMBUSTION is the rapid combination of fuel with oxygen; chemically speaking it is the combination of chemical elements producing heat. The chief elements of the fuel are carbon and hydrogen, which if brought in contact with enough oxygen under a high temperature will form substances altogether different from either. These different substances are called chemical compounds and in every chemical compound there exists an attraction between a definite and unvarying proportion of its elements known as chemical affinity.

There is, however, a great difference between a chemical compound and a mechanical mixture; for instance, atmospheric air is a mechanical mixture of oxygen and nitrogen, while water is a chemical compound consisting of hydrogen and oxygen in exact proportions of 1 to 8 by weight, and any chemical compound of oxygen and hydrogen in other proportions would be a substance entirely different from water, while air may exist in varying proportions and can easily be separated, in fact, we are doing it continually with our lungs. Water, however, or any other chemical compound, cannot be separated so easily. Combustion may be perfect if the proper supply of air and the proper temperature exists, and where this is not the case the combustion is imperfect and results in a great loss of heat.

This can be clearly illustrated with figures. For instance, if a pound of carbon is converted into carbonic oxide (CO), which is the first process of combustion it will generate 4,400 B. T. U. of heat. If, however, this imperfect product of combustion (CO) receives another equal supply of air a product of perfect combustion, carbon dioxide (CO_2), may be obtained, providing the temperature of both substances is high enough, and 14,600 B. T. U. are then generated, or in other words, nearly three times the amount of heat is generated by simply supplying enough air at the right time and of proper temperature. In imperfect combustion some of the hydrogen, together with the carbon with which it is usually combined (especially in Western coals), forming the volatile matter, may be distilled from the coal and not burned, or the hydrogen only in this volatile matter may be burned, leaving the carbon in the form of soot or smoke to be carried off in the gases passing out of the furnace.

It is claimed by William Kent in his new book on steam-boiler economy that all of the products of imperfect combustion, the carbonic oxide, the hydrocarbon gases distilled from the coal and the soot and smoke may afterwards be burned if they are carried into a very hot chamber where they are brought in contact with a sufficient supply of highly heated air. Statements similar to this had formerly been denied, but Kent has made an experiment which he claims proves that it can be done. He placed a short piece of candle inside of a tall narrow tin cylinder. The deficient supply of air the candle thus received caused it to give off a column of black smoke. This was caused to pass into the central draft tube of a Rochester kerosene lamp, and as it passed up into the flame of the lamp it was completely burned,

not a trace of smoke being visible in the lamp chimney. For years back the writer has maintained that smoke can be burned, although it is very difficult and costly, and it is evidently far cheaper to prevent smoke. If an engineer would study the construction and operation of a common kerosene lamp and experiment with it occasionally he would learn more about combustion in an hour than he otherwise could with a steam boiler furnace in a year. For instance, why is a glass chimney put on a kerosene lamp? Why is a perforated plate attached on a lamp below the flame, and why is the wick made narrow and long instead of round and bulky, and why is a gas tip slotted instead of simply having a round hole through which the gas escapes? Why does the Welsbach burner give a better light with less gas than an ordinary gas burner? Many more such questions might be asked, and I know many would not hesitate for a moment to try to answer them, and yet it is the identical process of complete combustion which ought to take place under a steam boiler.

If a kerosene lamp is smoking in your house you would immediately try to stop it; now why not do the same with a steam boiler furnace? Visible flame under a boiler is evidence of imperfect combustion. The product of perfect combustion of carbon is invisible carbonic acid gas and that of hydrogen is as invisible as vapor of dry steam. If we take a lighted central draft kerosene lamp and adjust the wick to such a point that the lamp gives a rather short and clear white light without a trace of smoke, then gradually obstruct the opening at the bottom, the following result is observed: the flame grows longer and its whiteness changes to yellow and then to red and it begins to smoke and finally when the air supply is nearly shut off the flame has risen to nearly the top of the chimney and a dense column of black smoke and soot is given off. We learn from this that perfect combustion may take place rapidly with a short flame or slower with a long flame, or imperfect combustion takes place with a very long flame of a low temperature with the same amount of fuel, but different results regarding heat and light.

The principles learned from these simple experiments with the flame of a lamp are of great importance in connection with the study of the action of steam boiler furnaces. Bituminous coal contains usually from 52 to 84 per cent. of free carbon and from 12 to 48 per cent. of hydrocarbons, that is, chemical mixtures of hydrogen and carbon. When soft coal is burned in a common furnace the coal is first heated, and the hydrocarbon gases are driven off in such quantities that not enough heated air can reach them to give perfect combustion and dense clouds of black smoke will escape through the chimney. A large number of heat units are thus lost until all the hydrocarbons have gone and the pure coke left, when the chimney will stop smoking and the combustion begin to get more perfect until a fresh charge of fuel is dropped on the hot coke, when the same performance begins over again. This is more evident as the volatile matter the coal contains increases.

All Western coal contains large quantities of volatile matter.

The proper amount of air has a great deal to do with the efficiency of the furnace. The highest efficiency has been obtained with 19 pounds of air per pound of coal, and it may be stated that the temperature in the furnace is the highest when the air supply is the smallest, providing the combustion is perfect, and any excess

of air will have a tendency to reduce the temperature in the furnace and consequently lower the efficiency.

In nine-tenths of the boiler rooms the engineers or firemen are working in the dark regarding the efficiency of their boilers and furnaces, no provision being made to measure the temperature and quantities of fuel and water, and everything being done by guess work. Every boiler room should have a draft gauge, a few thermometers to measure feedwater and flue gases, a pair of testing tanks and a reliable scale to enable the engineers to find out what is being done. He would very soon stop up all the cracks in the brickwork of his boiler to prevent the cold air from rushing in, which is so frequently the case. He would soon discover whether he had too much or not enough grate surface, for his flue temperature would tell him the story very plainly. There is no necessity of letting the temperature of the flue gases be more than from 50 to 100 degrees higher than the temperature of the steam. Some years ago an attempt was made to heat the air before it entered the furnace, but all furnaces so constructed have practically proved a failure unless the heated air was forced through the fire, and I have my doubts as to whether air can be heated higher than 180 degrees unless it is put under pressure.

When heavy fires are carried in a common furnace the conditions are apt to approach to those which obtain in the operation of gas producers. In these a thick bed of incandescent coal is provided and the supply of air is reduced, the object being to convert the carbon in the coal to carbonic oxide, and not to completely burn it. A report recently came to my knowledge where the flue gas analysis from a 12-inch bed of fire of a common furnace showed 6.8 per cent. of carbonic oxide, 1.7 per cent. free oxygen, and 11 per cent. of carbonic acid. After reducing the thickness of the fire 6 inches the carbonic oxide was reduced to ½ of 1 per cent., the free oxygen showed an increase to 3 per cent., and there was an increase in carbonic acid of 5 per cent. In this case the loss of heat from imperfect combustion with the heavy fire was 25 per cent. of the total heat of combustion in the coal, and needless to say a large column of black smoke escaped from the chimney.

Some firemen apparently feel proud when their chimneys make a long black mark across the sky. They are generally of the class of people who don't know and who don't wish to know. This is also the case, I am sorry to say, with a number of engineers. In large establishments in Europe the fireman gets a premium if he gets beyond a certain point of economy, and I think it would be a good plan to do that here.

To solve the problem of perfect combustion numerous devices for burning coal have been constructed and patented with more or less success. To name them all would be of very little value, but it may be of interest to describe some of the successful ones. One of the most successful in smoke prevention and economy is the so-called down draft furnace, which follows the process of a kerosene lamp. The coal in this furnace burns from the bottom, that is, the flame is led away from the fuel just as with a candle or a kerosene lamp. The gases are thus distilled off slowly and afforded an opportunity to come in contact and mingle with the proper amount of heated air. The grates on which the coal is laying must be, of course, water grates, otherwise they would burn up, and underneath these water grates

is a set of common grate bars. The coke which is dropped through the water grates by slicing is burned on the common grate completely. In this furnace the excess of heated air which passes through the lower grate is necessary to form a complete combustion of the hydrocarbons which may pass through the water grates with a deficient amount of air. With this type of furnace an almost entirely smokeless chimney and a large economy can be obtained if handled with a reasonable amount of intelligence.

Engineers have been known to declare that the down draft furnace, on account of the draft going first downward and then upward, works against nature. This, however, is a mistaken idea, and if these engineers would give the subject any thought whatsoever they would discover that just the contrary is the case, for the object of a down draft furnace is to lead the flame away from the coal in a manner similar to a burning candle or kerosene lamp. The fuel, however, is applied wrongly in a common furnace, generally speaking, but it is very difficult to do it otherwise, as the fresh coal can scarcely be put in between the burning coal and the grate; and if this could be done a down draft furnace would not be necessary in order to secure perfect combustion. The inventor's idea of the down draft furnace was therefore to prevent the freshly applied coal from being immediately surrounded by a mass of hot flame which would decompose the fuel too rapidly and therefore drive off large quantities of hydrocarbon gases which would not come in contact with a sufficient amount of heated air to form perfect combustion, the result being black smoke and loss of heat.

It is thus evident that the flame should burn away from the coal and the gases will then be distilled off slowly. This can be done even on a common grate only with a less economical result. For instance, if fresh fuel is spread on the front part of the grates of a common furnace it would be heated more gradually, would start to coke and by and by will be set afire. This fire should be worked back with a hoe and fresh fuel should take its place, instead of being dropped right on top of the hot fire. A common furnace worked this way would be practically smokeless. Of course the amount of fuel burned could hardly exceed 12 to 15 pounds per square foot per hour and the economy would be decreased on account of the doors being opened too many times for quite a while at a time, thus admitting a large quantity of cold air unless the damper is closed each time, which, of course, is too troublesome.

If a common furnace is fired any other way than this it will smoke every time it is charged with a fresh supply of fuel. While a thin bed of fuel is the proper thing on a common grate, a thick one is the proper thing in a Hawley furnace. This, however, does not seem to be understood by the majority of engineers and firemen, and the latter furnace is sometimes handled wrongly by simply keeping the bed of fuel on the water grate too thin and allowing the freshly distilled gases to be drawn in with too much cold air. This decreases the economy and may cause the chimney to smoke, which is certainly not necessary if fired properly.

Smoky chimneys are no more necessary than boiler explosions or pounding engines and can entirely be avoided, and I hope the day is not far off when an engineer will feel just as proud of his smokeless chimney as he does now of his noiseless and economically running engine.

The efficiency of steam boilers, especially in the western states, is frequently less than 50 per cent., while it is quite possible to raise this to 70 or even 78 per cent. with a down draft furnace. The raising of the efficiency of boilers from 50 to 75 per cent. would mean a saving of many millions of dollars per year. It would prevent a great deal of hard labor and would abolish the smoke nuisance which is now an increasing one, especially in large cities where manufacturing establishments are rapidly increasing in number. Of course, if a fireman wants to make smoke he can do so. There will never be a furnace invented that is fool proof, but in the majority of cases it is the fault of the owner when the chimney smokes. I have much sympathy for some of those unfortunate firemen and engineers that are compelled to work for small wages in underground and unsanitary hot boiler rooms, where ventilation is considered a luxury, and where they are compelled to work twelve hours a day and seven days in the week, and are expected to keep up steam and do it economically. How absurd and foolish it is when the owner of a plant thinks he can gain economy by taking it out of the fireman's hide, and I don't think I am far out of the way by saying that 75 per cent. of the owners are trying to do this every day, with the result of poor economy and smoky chimneys. The smoke inspector of every city should insist that proper equipment and facilities shall be provided for preventing smoke, and only when this is done is it just to blame the engineer or fireman for smoky chimneys.

GROUND DETECTORS

Cause of Grounds on Electric Lines—Methods of Testing for Grounds

When an accidental connection between a line wire, forming a portion of an electric circuit, and the ground occurs, the line wire is said to be grounded. If the electric circuit is permanently connected to ground on one side, as is a single trolley circuit, a ground connection between the trolley wire and the rails or earth will, if the accidental ground connection has low resistance, form a short circuit between the trolley wire and ground. A large current will flow and may do considerable damage if the circuit is not immediately broken by the circuit breakers at the power house. If one ground occurs on one of the two wires of a metallic circuit, which is otherwise free from grounds, no current will flow through the ground connection, but if, while the first ground is on, a second ground occurs on the other side of the circuit, a connection between the two sides of the circuit through the ground is established, and the amount of current flowing through this ground connection will depend upon the E. M. F. of the line and the resistance of both grounds. Grounds may be caused by a variety of means. On line wires an insulator may break and allow the insulation of the wire to be rubbed off upon the pole, thus bringing the wire into connection with the ground through the pole, if the pole be made of iron, or if of wood that is well soaked with rain. Line wires may also come in contact with other wires that are connected to ground. In interior wiring, the wires may come in

contact with the steam, gas, or water pipes and thus form a ground. Grounds may have a very high resistance and allow only a little current to leak

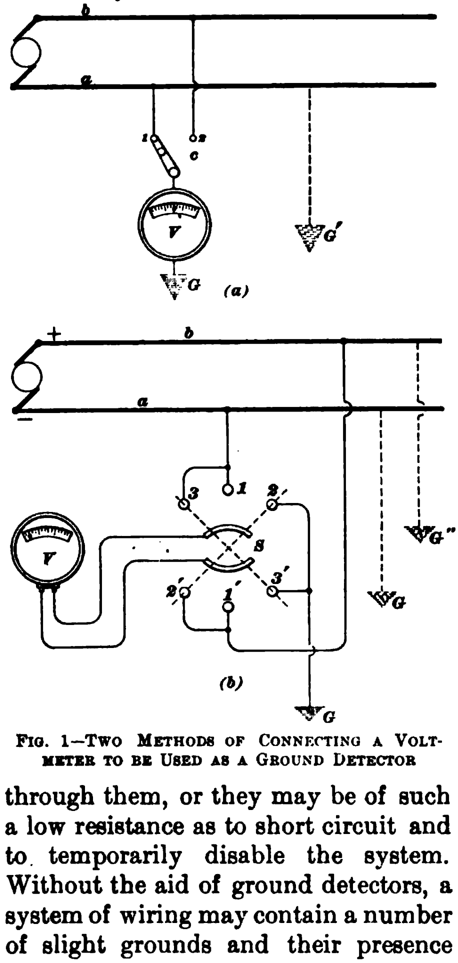


FIG. 1—TWO METHODS OF CONNECTING A VOLTMETER TO BE USED AS A GROUND DETECTOR

through them, or they may be of such a low resistance as to short circuit and to temporarily disable the system. Without the aid of ground detectors, a system of wiring may contain a number of slight grounds and their presence remain unknown at the station.

Ground detectors may be so connected as to indicate the presence of a ground at the time of its occurrence, or they may be normally out of connection with the line wires and only thrown into connection when it is desired to test the line for grounds. Following are connections and descriptions of a number of different kinds of ground detectors. A voltmeter can be readily used as a ground detector. It indicates both the presence of a ground and its comparative resistance. The voltmeter may be connected, as shown in Fig. 1 (*a*), for use with a direct-current circuit. The mains are indicated by *a* and *b* and are connected to points *1* and *2* of a two-point switch. The switch blade is connected through the voltmeter *V* to the ground. The zero on the scale of the voltmeter is at the center of the scale. The needle may be deflected either way, depending upon the direction of current through the instrument. If the line *a* should become grounded, as indicated by the dotted line, and the switch blade placed on point *1*, no deflection would result, as both the voltmeter and the ground are connected to the same side of the circuit. If the blade is placed on point *2*, current will pass from line *a* through the ground on the line to the voltmeter to point *2*, and thence to the line *b*, thus completing the circuit. When a deflection is obtained on point *2*, it shows that line *a* is grounded; and when obtained on point *1*, it shows that line *b* is grounded. If the ground is of high resistance, the deflection will be comparatively small; if of low resistance, the deflection will be large. Many direct-current voltmeters, for

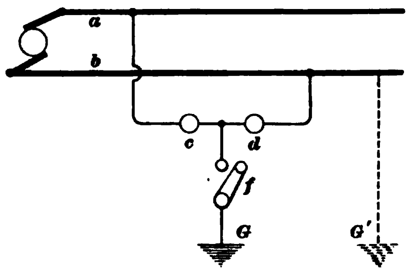


FIG. 2—METHOD OF DETECTING GROUNDS BY THE USE OF INCANDESCENT LAMPS

example, the Weston, require that the current shall flow in them always in the same direction, in order that they may give a deflection over the scale. In Fig. 1 (*a*) it is easily seen that the

current will flow through the voltmeter in the opposite direction on point *2* from what it will on point *1*, hence the voltmeter must have its zero point in the center of the scale, so that it can read either way.

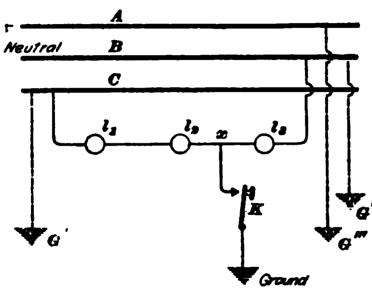


FIG. 3—LAMP GROUND DETECTOR FOR A THREE-WIRE SYSTEM

By means of a switch of special construction a single scale voltmeter can be used as a line voltmeter or a ground detector. Fig. 1 (*b*) shows an arrangement for doing this. The switch *S* is so arranged that when in position *1–1'*, the voltmeter *V* is connected directly across the line and gives the voltage on the system. When the switch is in position *3–3'*, the voltmeter indicates any grounds, such as *G''* that may be present on line *b*. When *S* occupies the position *2–2'*, *V* indicates grounds on line *a*, as at *G'*. By tracing out the path of the current in each case, it can be seen that the current always flows through the voltmeter in the same direction.

A common arrangement for detecting grounds is shown in Fig. 2. Here two lamps *c*, *d* are connected in series across the lines. The voltage at which these lamps are designed to run is equal to that of the dynamo, so that when the two are connected in series, they will burn dull red. At the point between the lamps, a connection is made to ground through a switch or a push button *f*. If *f* is closed and there is no ground on either line, the brilliancy of either lamp will not be altered. Suppose, however, there is a ground on *b*, as indicated at *G'*. Now, when *f* is closed, hardly any current will flow through lamp *d*, because the current will flow through *e* and *f* to the ground and thence to line *b*. In other words, lamp *d* will be shunted by the ground and it will go out. The cutting out of the high resistance of lamp *d* in series with *c* results in *c* burning brighter. The lamp that is connected to the side of the circuit on which the ground exists goes out or becomes dimmer, while the lamp on the other side brightens up correspondingly.

A somewhat similar type of ground detector can be applied to the three-wire system as shown in Fig. 3. The test lamps are represented by l_1, l_2, and l_3. They are connected across one side of the system. A ground connection is made at *x* through key *K*. When all three lines are free from grounds, the lamps will burn at a dull red, they will all be of equal brightness, and their color will not change when key *K* is pressed. Suppose that line *C* be-

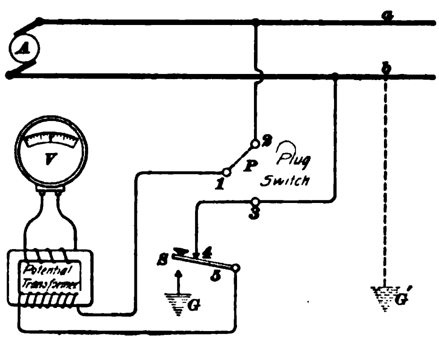


FIG. 4—GROUND DETECTOR FOR AN ALTERNATING-CURRENT SYSTEM

comes grounded at *G'*; then, when *K* is pressed, lamp l_3 will be connected across lines *B*, *C*, and lamps l_1 and l_2 will be cut out; l_1 and l_2 will therefore go out, and l_3 will come up to full candlepower. If a ground occurs at *G''* on line *B*, lamp l_3 will go out and

l_1, l_2 will brighten up, but will not come up to full candlepower because two of them will be in series between *B* and *C*. If there is a ground at *G'''* on line *A*, all the lamps will come up to full candlepower, because they will

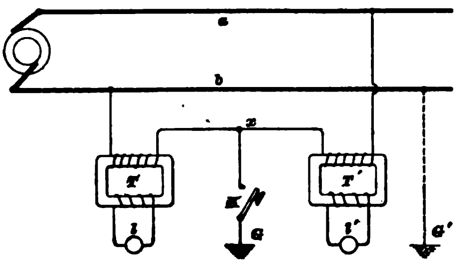


FIG. 5—HIGH-TENSION ALTERNATING-CURRENT SYSTEM GROUND DETECTOR

all get the full voltage, l_3 being across *A B* and l_1, l_2 in series across *A C*. It is thus seen that a ground on any one of the three lines affect the lamps differently, so that by noting their performance, the line on which there is a ground may be located.

Somewhat similar arrangements may be used for detecting grounds on alternating-current lines, except that potential transformers are used to provide a suitable E. M. F. for the voltmeter or lamps. Fig. 4 shows the method sometimes used by the Westinghouse Company. *V* is the regular switchboard voltmeter. *P* is a plug switch by means of which points *1* and *2* or *1* and *3* may be connected together. Under ordinary conditions, the plug is in *1* and *2*, thus connecting the primary of the potential transformer across the line, and *V* serves as an ordinary voltmeter. *S* is a key, or push button, that when pressed, connects one side of the line to ground through the transformer primary. If there happens to be a ground on the side *b*, as shown at *G'*, the voltmeter will give a reading, and the attendant can judge by the size of the deflection as to whether the ground is a serious one or not. The path of the current is *b–G'–G–5* to primary *1–2– a*. By placing the plug in points *1* and *3*, side *a* may be tested. When the key *S* is not pressed, the lever *5* is against contact *4*, so that *V* is connected as an ordinary voltmeter.

A ground detector that is suitable for high-tension alternating-current systems, is shown in Fig. 5. It is similar in principle to the lamp detector shown in Fig. 2. The lamps *l*, *l'* are connected to the secondary terminals of the small transformers *T*, *T*. The primary coils are connected in series across the high-tension lines. The test for ground is performed as explained in connection with Fig. 2.

A form of ground detector formerly used by the Thomson-Houston and General Electric Companies is shown in Figs. 6 and 7. In Fig. 6, *A* represents a laminated-iron core. On it is wound the coil *B*. The coil *B* is connected as shown. The lamp *l* is connected be-

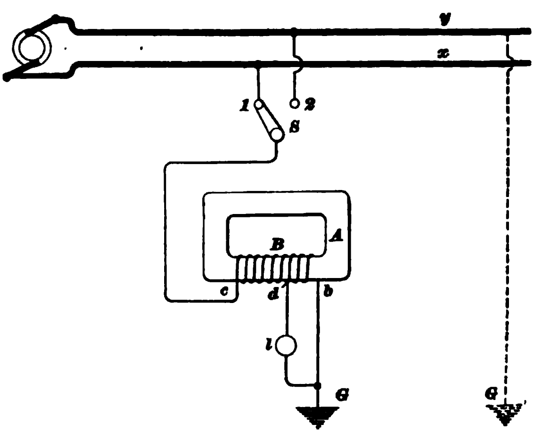


FIG. 6—GROUND DETECTOR FORMERLY USED BY THE THOMSON-HOUSTON AND GENERAL ELECTRIC COMPANIES

tween one end of coil *B*, and an intermediate point *d* on coil *B*. The test is carried out in a similar manner to the test described in connection with

Fig. 1 (*a*). If current flows through the coil *B*, an E. M. F. is set up between *d* and *b*, and the lamp is illuminated. Fig. 7 shows the general appearance of the testing set. Plug *p* can be used to connect the transformer to any of the lines in place of *S*, Fig. 6.

Ground detectors operating on the electrostatic principle are now used quite extensively. They require no current for their operation and may be left connected to the circuit all the time, thus indicating a ground as soon as it occurs. There is no actual con-

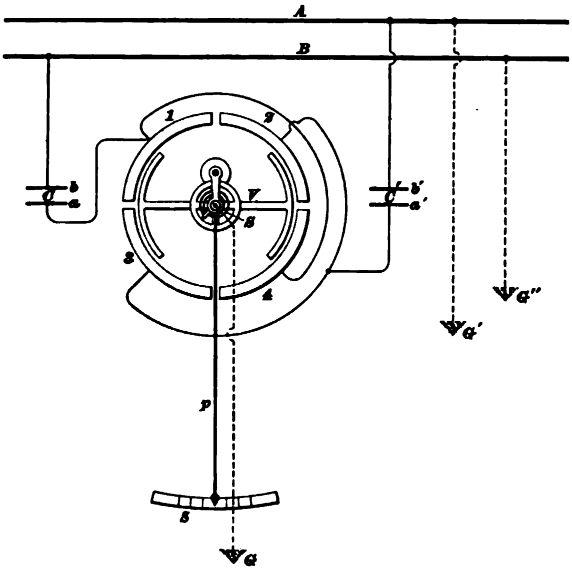


FIG. 8—STANLEY ELECTROSTATIC GROUND DETECTOR

nection between the line and ground.

Fig. 8 illustrates a Stanley electrostatic ground detector. The fixed vanes *1* and *4*, *2* and *3* are connected together in pairs, as shown. The movable vane *V* is connected to the ground. It is held in central position by means of small spiral springs *S*. The pairs of fixed plates are attached to plates *a*, *a'* of two small condensers. These condensers consist simply of two brass plates *a*, *b* that are mounted

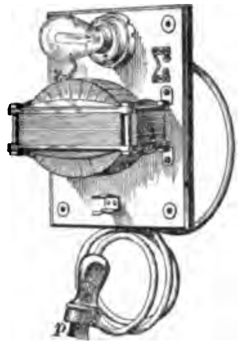


FIG. 7 — TESTING SET USED WITH DETECTOR SHOWN IN FIG. 6

in hard rubber at some distance from each other. When no grounds are present, *1* and *4*, *2* and *3* become oppositely charged by reason of charges induced on plates *a*, *a'* by plates *b*, *b'*. The forces acting on the vane *V* are, therefore, equal and opposite. Now, suppose that line *B* becomes grounded at *G''*. This is equivalent to connecting vane *V* to line *B*; *V* takes up a charge similar to *2* and *3*, hence it is repelled by *2* and *3* and is attracted by *1* and *4*, thus giving a deflection. If *A* becomes grounded, a deflection in the opposite direction is obtained. This kind of instrument is used in connection with high-tension lines. In some electrostatic detectors, condensers *C C'* are omitted, the fixed sectors being connected directly to the lines. The sectors are charged directly from the lines.

UNCERTAINTY OF THE TERM HORSEPOWER WHEN APPLIED TO BOILERS

THE most common method of estimating the horsepower of steam boilers is by means of the extent of the heating surface. The quotient obtained by dividing the total area of this surface by a certain unit of surface, represents the horsepower of the boiler. This method is used extensively by engineers, boilermakers, and dealers in machinery. When the unit referred to is properly chosen, the results are oftentimes in accord with the facts as determined by tests later on. It will be noticed in this connection that, while the total area of heating surface in any given boiler remains the same, the horsepower may be made to vary between widely separated limits by simply changing the unit of surface selected as equivalent to one horsepower. For this reason, buying steam boilers with capacity expressed by a certain number of horsepower has proved to be very unsatisfactory in a large number of cases and has led the purchaser to believe that the dealer or boilermaker, as the case may be, acted dishonestly. Paradoxical as it may appear to some, it is possible for a purchaser unfamiliar with the methods employed in boiler practice to be deceived by strictly honest means, having no one but himself upon whom to cast the blame for subsequent failures. It is the purpose here to illustrate how this may readily be accomplished and how it is being done almost daily.

The method outlined above of finding the horsepower of a boiler gives what is generally called the commercial horsepower, or the commercial rating.

An instance serving to illustrate the flexibility of the horsepower method of rating boilers when only the heating surfaces are considered, is that of a gentleman in Michigan who owned a tract of timber land and desired to reduce the trees to lumber on his own property. He purchased a sawmill of one party and a throttling slide-valve engine of another, both the engine and mill apparatus being second hand. The boiler had to be purchased new, and after some correspondence with builders of boilers their agents called and endeavored to sell him a boiler.

The sawmill required 45-brake horsepower when sawing the average sized log, and the engine developed 50 horsepower with a boiler pressure of 80 pounds and the cut-off set for one-half stroke. The purchaser had been cautioned not to buy a boiler of less than 15 horsepower more than the engine and, as will be seen, used this advance information, as he supposed, to good advantage.

One agent offered a boiler of 55 horsepower, containing 700 square feet of heating surface, and, to prove the rating liberal, cited an instance where a boiler of the same size was furnishing steam to a 75-horsepower Corliss engine without the slightest inconvenience. While the mill owner was trying to decide whether or not to accept the offer, another agent called and informed him that it would not be good economy to attempt to run the 50-horsepower engine with a 55-horsepower boiler. The latter agent offered a boiler of 65 horsepower at the same price and, of course, effected a sale. The latter boiler contained a trifle more than 670 square feet of heating surface. According to the figures presented by the agents, both were right and no doubt

were perfectly honest in their representations; at the same time, it is evident that the boiler credited with the greater horsepower was really the smaller of the two, although the external dimensions were the same. In the first instance the agent employed a unit of surface of 12½ square feet as equivalent to one horsepower, while the second selected about 10⅛ square feet.

This incident is cited to illustrate the fact that when buying steam boilers by the horsepower, as this term is generally employed, the extent of heating surface expressed in square feet should be selected for comparison instead of the figures representing the commercial horsepower or commercial rating.

When the so-called 65-horsepower boiler was put into service it was necessary to force the fires continually in order to produce the required amount of steam, and it was with considerable difficulty that the owner was dissuaded from believing that the agent acted dishonestly.

The unit area of surface equivalent to one horsepower varies considerably not only with different persons but for different types of boilers. Some persons employ the same unit area in estimating the capacity of the locomotive type as others do concerning the horizontal boiler, while still others have a separate unit for each design, so that when the capacity of a boiler is expressed in horsepower based upon the extent of heating surface, it conveys but a vague idea of the amount of water the boiler is capable of converting into steam in a given time. The flexibility of this method of rating boilers is to a great extent responsible for illy-proportioned boilers because many persons who are not familiar with calculations of this kind but are close figurers and shrewd are led to buy boilers on small margins, which when put into service prove to be too small for the work expected of them.

Agents and dealers sometimes take advantage of the possibilities of this method and change the horsepower of a given boiler to meet the needs of the purchaser, a single size of boiler being referred to and sold in place of a variety of sizes.

The term horsepower applied to a steam boiler conveys to many minds something about the size or horsepower of engine the boiler is capable of supplying with steam, but unless the unit of surface is given upon which the horsepower is based even then it fails to give a correct impression of what the boiler may reasonably be expected to do. To other minds it has practically no meaning and suggests no idea of the real capacity of the boiler for generating steam. The reason is, that the amount of steam required to produce one horsepower varies considerably with different styles and makes of engine so that it depends largely upon the size and style of the engine whether a boiler of a given commercial rating will furnish the required amount of steam economically, all things considered. For example, take a boiler of 100 horsepower commercial rating; ask an engineer what sized engine the boiler will be capable of supplying with steam economically. If he is conservative in his estimates he will probably say, from 80 to 100 horsepower, depending upon the style of engine employed. When the unit area of surface equivalent to one horsepower is given he will be able to designate the style and size of engine best adapted. But here is where the uncertainty of the horsepower method is felt, because it is not customary to state the unit area when giving the horsepower of a boiler. It is no doubt readily comprehended how a person unfamiliar with boiler calcu-

lations may be easily led to select a boiler wholly unsuited to his requirements.

It becomes almost necessary to first know the dimensions of the boiler, and second, the weight of steam required by the several types of engine in order to be able to make a reasonably close estimate of the size and style of engine to which the boiler will be best adapted. If the 55-horsepower boiler previously referred to is capable of evaporating say 1,265 pounds of water per hour from and at 212 degrees, then it would furnish steam for a 45-horsepower engine requiring not more than 28 pounds of steam per horsepower hour. If the steam consumption were as low as 20 pounds per horsepower hour the same boiler would be adapted to drive a 63-horsepower engine, but with a steam consumption of 32 pounds it could only be expected to furnish steam to an engine of 39 horsepower. It will be readily understood that it is important to know the style of engine it is intended to use and the corresponding average steam consumption. On the other hand the style of engine will oftentimes affect the actual rating of the boiler.

As the steam consumption of the engine increases, the actual horsepower of the boiler relative to the engine, decreases. Assume a boiler capable of evaporating 3,200 pounds of water per hour from and at 212 degrees. If the engine requires 28 pounds of steam per horsepower hour the boiler would be said to be of $3{,}200 \div 28 = 114$ horsepower. Should the engine require 32 pounds, the boiler would be said to be of $3{,}200 \div 32 = 100$ horsepower. When proportioning boilers to engines some engineers allow about 11 square feet of heating surface for each rated horsepower of the engine for four-valve non-condensing engines; 12 square feet for single-valve automatic cut-off engines, and 14 or 15 square feet for throttling engines, making some allowance for the possibility of the engine working beyond its rated power.

While this method of rating and proportioning boilers is in daily use and the results relied upon by those accustomed to using it, it cannot be said to be very convenient even for estimating because considerable data must first be obtained and if this cannot be done then certain quantities must be assumed and the value of the result will then be in keeping with the amount of practical experience possessed by the person making the calculations.

There is another method frequently employed by dealers for estimating the probable capacity of a boiler. While it is an improvement upon the method previously considered it may be well to call attention to one or two ways in which the results may be modified to suit the desire of the persons making the calculations. In these calculations the term horsepower is not necessarily employed, the capacity of the boiler being expressed in pounds, which refers to the probable evaporation from and at 212 degrees per hour. In order to determine the size or the horsepower of an engine a boiler of a given evaporative capacity is capable of supplying with steam, it is only necessary to divide the probable evaporation by the steam consumption of the particular engine or of the style of engine to be used. The average steam consumption of single-valve non-condensing engines is taken at about 30 pounds per horsepower hour; four-valve engines, 26 pounds; compound, 22 pounds. For condensing engines these figures are reduced about 15 per cent. An engine of 100 horsepower requiring 30 pounds of steam per horsepower hour will

require a boiler capable of evaporating 3,000 pounds of water in the same length of time. This same boiler when supplying steam to an engine requiring 22 pounds will be capable of furnishing steam to an engine of $3,000 \div 22 = 137$ horsepower. It will be seen that by this method the horsepower of a boiler relative to the engine is obtained by dividing the capacity of the boiler expressed in pounds by the steam consumption of the engine per horsepower hour.

It has no doubt been noticed that the horsepower method of rating boilers, based upon the extent of heating surface only, does not take into account the fact that the probable capacity of a boiler, however it may be expressed, depends to a great extent upon the heat generated in the furnace, and this in turn depends upon the weight of fuel burned. It becomes necessary, therefore, even when making rough estimates, to take into account the necessary quantity of fuel to produce a given evaporation.

There are several formulas employed for making estimates of the probable capacity of boilers. The one more generally employed is $.0222\ R^2 + 9.56\ C =$ pounds of water evaporated from and at 212 degrees per hour for each square foot of grate surface, in which R represents the ratio of heating surface to grate surface and C the weight of coal burned per square foot of grate surface per hour. The ratio of heating to grate surface is found by dividing the area of the heating surface by the area of the grate surface, both expressed in square feet. To illustrate the application of the formula, assume that a boiler contains 1,200 square feet of heating surface and 25 square feet of grate surface, and that 15 pounds of coal are to be burned on each square foot of grate. The probable evaporation is $.0222 \times \left(\frac{1,200}{25}\right)^2 + (9.56 \times 15) = 194.54$ pounds per hour for each square foot of grate and the total evaporation will be $194.54 \times 25 = 4,863.5$ pounds. This represents about the maximum evaporation that may be expected with hand firing under favorable conditions so that some margin should be allowed above the average requirements of the engine when selecting a boiler for one of given size and horsepower.

It will be noticed in the foregoing illustration that the apparent capacity of the boiler may be increased or decreased as desired, by simply changing the figures representing the weight of coal consumed per square foot of grate per hour. Had the weight of coal been 30 instead of 15 pounds the capacity would have been increased to 8,453.5 pounds per hour. To obtain this figure would be possible, but it is much higher than could be hoped for under anything less than extraordinary conditions. It is evident that it is a good plan to obtain some idea about the limit of the weight of coal that can be regularly burned per square foot of grate, before attempting to rate boilers in this manner. Without this information it is quite probable that an inexperienced person would be led to purchase a boiler much too small even with this method of determining the proper size.

When proportioning a boiler to an engine or when ascertaining the capacity of a boiler of given size it is well to use a conservative figure representing the weight of coal burned per square foot of grate. Fourteen or fifteen pounds per square foot is high enough and should not be exceeded for hand-fired boilers with natural draft, while from 11 to 13 pounds will be found still better. It requires a strong draft

and skilful firing and a fair grade of coal to be able to properly burn 20 pounds of coal and upward on each square foot of grate per hour. With forced draft this figure is frequently exceeded but it is not good policy to proportion a boiler so as to require this rate of combustion at the outstart.

An instance serving to illustrate the flexibility of the latter method of rating boilers is that of a mill in which two boilers were installed, supplying steam to a large automatic cut-off engine, two smaller engines for driving blowers, and for heating two large buildings with live steam. Each boiler contained 1,050 square feet of heating surface and 24 square feet of grate surface. The total weight of steam required per hour was approximately 10,500 pounds. The person who selected the boilers maintained that a rate of combustion of 24 pounds of coal per square foot represented good practice and consequently employed that figure in proving the capacity of the boilers ample for the work. Assuming the rate of combuition given above the capacity of each boiler is

$$.0222 \times \frac{(1050)^2}{24} + (9.56 \times 24) \times 24$$

$= 6526.3$ pounds per hour or 13,052.6 pounds for both boilers. The boilers were apparently ample in size and capacity, but when in actual service it was difficult to burn even 20 pounds of coal per square foot of grate owing to the changes in the intensity of the draft and the inability to keep the grates free of clinkers. When forcing the fires to the utmost under the conditions existing it was found possible to carry the full load, but not without a considerable waste of fuel.

Attention is called to these two methods of estimating boiler capacity because they are very largely used by the majority of running engineers as well as other persons who, not possessing a practical knowledge of boilers and boiler practice rely implicitly on the results thus obtained.

The illustrations presented also emphasize the fact that all the data possible should be obtained when selecting a boiler for any purpose and that when information concerning the conditions cannot be obtained it is necessary to make a liberal provision for more or less unfavorable conditions that are very apt to be found when least expected.

SUPERHEATED STEAM

NOW that superheated steam is occupying much attention as an economical agent in engines practical difficulties in its action are being discussed. One of the most serious is the friction of the piston in the cylinder, the great heat rapidly dissipating by burning any oleaginous compound that is introduced. A prominent British firm who have used superheated steam for many years, at a temperature of 550°, says that the wear in six years of the piston packing was only $\frac{1}{8}$ of an inch, the packing being of the Ramsbottom type. Against this testimony a correspondent of a technical journal states that he tried many agents to reduce the wear of the packing, and finally employed a mixture of mica, grease, and graphite, which answered well and was adopted. It seems that superheated steam requires a special piston, which is described as one with cast iron rings of the eccentric type, not snapped in but having bull rings and a follower, so that the rings may be put in place without distortion —Scientific American.

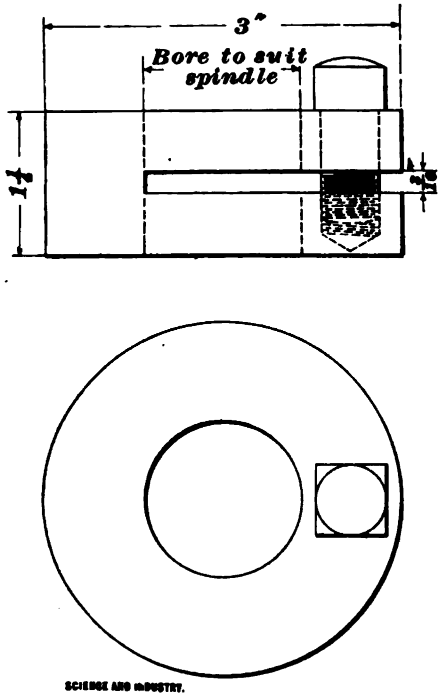
USEFUL IDEAS

STOP COLLAR FOR DRILL SPINDLE

I enclose a contribution for your "Useful Ideas" department, which is nearly self explanatory:

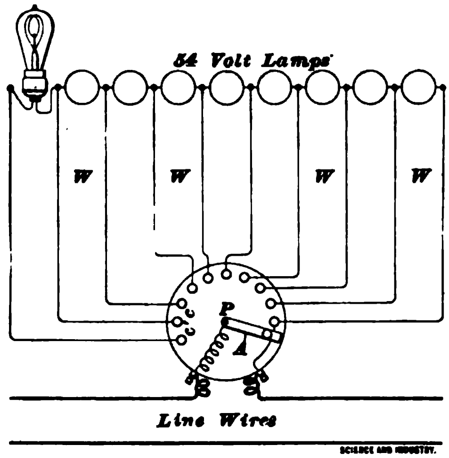
In many shops the drill presses have no stop on the spindle, and when it is necessary to drill holes a certain depth the cut-and-try method is very often adopted, which, to say the least, is wasteful of time. I have used the collar as sketched with good results when slotted out in the manner shown, and made a nice fit for the drill spindle. The setscrew, upon being tightened, will bind the collar wherever it is placed without in any way injuring the spindle. The cost is trifling and will repay the trouble of making.

H. J. W.



A SIMPLE RESISTANCE BOX

I have noticed in two recent editions of SCIENCE AND INDUSTRY different ways of constructing starting boxes and rheostats. I enclose a drawing of a resistance box which I made for my shop. It consists of nine 54-volt lamps connected in series. One line wire is connected to one end of the last light, and the other is connected to one end of the handle *A*. This handle turns on a pivot *P*, and can be placed in contact with any one of the contact points *c*, *c'*, etc., which are connected by wires *W* with the lights, as shown. By placing the handle at *c'*, the resistance occurs in the whole nine lights and by moving the handle the resistance decreases. When the handle is turned way around the only resistance is in one light. By moving the handle backward the resistance increases.



If more resistance is required 54-volt lamps can be changed for lamps of higher voltage.

EDITORIAL COMMENT

The regular meeting of the Engine Builders' Association of the United States was held at the Schenley Hotel, Pittsburg, Pa., on May 22 and 23. President W. M. Taylor, of the Chandler & Taylor Engine Co., of Indianapolis, opened the proceedings with an address. H. F. J. Porter, of the Bethlehem Steel Co., read the first paper, taking for his subject "Engine Forgings." The paper described at length the methods followed out which have resulted in the ability to build the enormous parts of modern engines and electrical machines.

The second paper was read by E. M. Tingley, of Pittsburg, who discussed "The Engine Requirements for the Parallel Operation of Alternators."

John H. Berryman, of Chicago, read a paper on "Piping Materials for Steam Plants," and H. M. Longwell, of Pittsburg, took for his subject "The Requirements for the Paralleling of Alternators as Viewed by Engine Builders." The papers were all of a high character and were listened to with great interest by those present.

The proceedings closed with a banquet on the evening of the second day.

A Summer School for Apprentices and Artisans will be conducted under the auspices of the College of Engineering of the University of Wisconsin, at Madison, Wis., from June 30 to August 8, inclusive.

The school was started last year as an experiment, and that it was an eminently successful one is evidenced by the number of personal endorsements afterwards sent to the faculty by those who took the courses.

The purpose of the school, as outlined in the circular, is to give stationary engineers, superintendents of power stations, machinists, artisans, and apprentices in various trades such mathematical, laboratory, and shop instruction as will be found of most practical value to them.

Any person over 16 years of age, speaking the English language and having a fair knowledge of arithmetic, will be admitted. The school has a faculty of ten, composed of regular professors and instructors on the faculty of the College of Engineering.

Correspondence school students will find the opportunities for laboratory and shop work here offered particularly helpful. We believe that this is a move in the right direction and one that will be a great help to many ambitious men.

One of our subscribers desires information in regard to the use of gas engines in electric-light plants. If any of our readers know of any stations where gas engines are used and will advise of their location and the name of the company operating them, we shall endeavor to procure the desired information.

Mr. N. L. Frothingham, attorney and counsellor-at-law, has moved both his New York and Boston offices, the new addresses being 53 State Street, Boston, Mass., and 271 Broadway, New York City. Mr. F. T. Wentworth will continue in charge of the New York office.

Our July supplement consists of a table of dimensions of magnet wire. The sizes run from No. 0000 to No. 36 B. & S. gauge, and the dimensions are given for bare wire and for single, double, and triple cotton-covered.

BOOK NOTICES, CATALOGUES, AND TRADE NOTES

SELF-PROPELLED VEHICLES. By James E. Homans, A. M. Published by Theo. Audell & Co., New York.

The subtitle of this work states that it is a practical treatise on the theory, construction, operation, care, and management of all forms of automobiles. This is a pretty broad title, but an examination of the book proves that it is just what it claims to be. The author's aim throughout appears to have been to present the various theories and problems of construction and operation clearly, fully, and with careful attention to important details. The reader is thus enabled to grasp the involved situations and understand the "why" and "wherefore" of many of the devices—foreign alike to horse carriages and railway locomotives. The book consists of 640 octavo pages, containing nearly 500 illustrations and diagrams, covering nearly every type of practical device used on power-driven carriages. Several useful tables are included in an appendix, and the book is closed with a very full and carefully prepared index. "Self-Propelled Vehicles" is a decidedly valuable addition to automobile literature.

SPANGENBERG'S PRACTICAL ARITHMETIC, by E. Spangenberg, C. E. Published by Geo. A. Zeller, St. Louis, Mo. Price, 50 cents.

This is a practical little book for the practical man. It is not intended as a textbook for the schoolroom, but for adults whose early education has been neglected, or who have forgotten what they once knew about the subject of arithmetic. It explains the important points of elementary mathematics in a clear manner, which should be understood by any one of average intelligence. There is a table of weights and measures in the back, giving equivalents for all denominations. The book is bound in pocket size, and is one which should prove of considerable value to those for whom it is intended.

ESTIMATING FRAME AND BRICK HOUSES (second edition, revised and enlarged), by Fred. T. Hodgson. Published by David Williams Co., New York. Price, $1.00.

This is a practical treatise on estimating the cost of labor, and the quantities of materials necessary for the construction of frame and brick houses, and of stables, barns, etc. The subject is dealt with in a thorough manner and the text made clear by the use of illustrations where necessary. It will be found a very useful book for those interested in the subject.

The Joseph Dixon Crucible Co., Jereys City, N. J., have issued an attractive little pamphlet showing some excellent half-tone cuts of prominent structures which have been painted with their product.

The Edge More Iron Co., Edge More, Del., manufacturers of boilers, have issued their catalogue for 1902. The catalogue is unusually well gotten up, being bound in stiff silk cloth covers and illustrated with excellent half-tone engravings.

We are in receipt of the catalogue of the Norton Emery Wheel Co., Worcester, Mass., giving complete descriptions of their products. The catalogue is profusely illustrated, and altogether presents a very attractive appearance.

Armstrong Bros. Tool Co., of Chicago, report a marked increase recently in the export demand for their tool holders. They have recently established agencies in Australia and New Zealand which give every promise of developing into important markets for the company's product. Some time ago the company sent Mr. Nestor Johnson into Norway, Sweden, and Denmark to investigate that market and to introduce the Armstrong tools. Mr. Johnson, who is a native of Norway, and a practical mechanic of wide experience, met with the most gratifying success. He has recently returned to Chicago after placing the Armstrong agency for the countries of Norway, Sweden, and Denmark with the firm of C. S. Christensen, of Christiania, Norway. Mr. Johnson relates many interesting experiences which he had while traveling in the company of one of C. S. Christensen's engineers, visiting the largest machine shops in the countries above named. One of the most interesting of these occurred at the plant of the Moss Mechanical Works, at Moss, Norway, while making a demonstration of the Armstrong Gang Planer Tool at the request of Mr. Karl Olson, superintendent of the works. The subject of the test was a large cast-iron plate used in connection with pulp-mill machinery, and Superintendent Olson announced their regular time on this job as seven hours. Mr. Johnson and the Gang Planer Tool finished it in just 1¾ hours. Numerous large orders for Armstrong tools

and self-hardening steel sent in subsequently by C. S. Christensen testify to the practical and convincing nature of Mr. Johnson's work and the merits of the tools he introduced.

The Cornish Co., Washington, N. J., manufacturers of pianos and organs, is one of the most progressive concerns of its kind in the country. They have a host of testimonials from people who have used their instruments for from eighteen to thirty-six years, and which prove the high degree of satisfaction which they give. They sell directly from the manufacturer to the consumer, thus saving the middleman's profit. Any one contemplating the purchase of a piano or an organ should not fail to correspond with this company.

A new nipple holder has been made by the Armstrong Mfg. Co., of Bridgeport, Conn., to be used in connection with their No. 00 pipe-threading machine. It holds pipe from 1 inch to 4 inches, inclusive, by using different threaded rings and backing pieces.* It will also hold close nipples either right hand or left hand, no change of parts being necessary to hold the nipple for threading it left hand. When the thread is cut the nipple can be removed with the fingers by loosening the screw in the back of the holder. This nipple holder can be furnished to hold as small as ¾ inch if required.

The Union Steam Specialty Co., in order to take better care of their work, placed an order on May 3 with the Prentiss Tool & Supply Co., Liberty St., New York, for one 60-inch Pond lathe, one 60 × 72-inch Pond planer, one 54-inch Rogers & Hemphill vertical boring mill, and one large Bickford radial drill. In addition to this they purchased a short time previous, of the same company, eight smaller lathes and four planers, the tools represented by these recent orders amounting to over $30,000. As it stands now their factory is equipped with the smallest jewelers' lathes for their indicator work, and from this they can easily handle the largest triple-expansion water-works pumping engine. Their factory covers over two acres, and being located in the heart of the coal and iron regions, and with their exceptional shipping facilities, they claim that they are in a position to at least equal any concern on earth in their line. Their new catalogue may be had by addressing them at 1614 Franklin Ave., Scranton, Pa. In addition to their line of indicators, this catalogue shows reducing wheels, planimeters, shaking grates, furnace blowers, steam pumps, etc.

The superiority of France metallic packing over that of other makes has been fully demonstrated in the recent competitive tests with metallic packing of similar character manufactured by several concerns engaged in such industries. After a competitive test it has been adopted by the Metropolitan Street Railway Co., New York, for their eleven 7,000-horsepower engines; New York Gas and Electric Company for their eight 7,500-horsepower engines; Brooklyn Edison Company for their two 7,000-horsepower engines; Boston Elevated Railway for their two 7,000-horsepower engines; and the New York Central & Hudson River Railroad for their stationary work. It is also used in equipping the Manhattan engines in their large power house in New York city, in addition to several other large contracts. A booklet on packing and a handsome match box will be sent free to chief engineers and large steam users, who are interested in high grade metallic packing by A. W. France, Tacony, Philadelphia. Mr. France will also send a copy of his catalogue illustrating and describing his complete line of packings upon request. Kindly mention this paper when writing.

To meet the demand of increasing business, The Merwarth Metallic Casket Co. have moved from 107 Liberty street into larger quarters in the Beard Building at 120 Liberty street, Rooms 604 and 605, New York City.

The ability of the American engineer to design steel structures of great strength and pleasing architectural effect, is shown in the eight half-tones on the handsome souvenir mailing card issued by the Joseph Dixon Crucible Company, of Jersey City, N. J. The card is a piece of artistic advertising on the part of the company, and will prove of decided interest to constructing engineers and architects, to whom it will be sent on request.

Dixon's Silica-Graphite Paint, which protects these structures from corrosion, has been very extensively used in the south, west, and seacoast sections of the United States, also in Mexico, Australia, China, Japan, West Indies, and Philippine Islands, and has proven its protective and wearing qualities in all climates.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

MECHANICAL

(181) What kind of tools are used for scraping a worn brass box of a gas engine, or where can I get a book that gives practical information on this subject?

N. T., Page, N. Dak.

ANS.—A tool called a scraper is used for this purpose. It is generally make by taking an old file and grinding the teeth off of it, leaving the edges sharp. The Course in Shop Practice taught by the International Correspondence Schools, Scranton, Pa., contains information on subjects of this kind.

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(182) I have charge of a double hoisting engine having cylinders 9×14 inches. If a flywheel is placed on one engine will it do the same work that was formerly done by both engines without the flywheel?

H. S., Streator, Ill.

ANS.—No; the purpose of a flywheel is to promote uniformity of turning effort on the part of the engine, and it in no way serves to increase the power of the engine. The power of any engine is equal to the product of the mean effective pressure, the length of stroke, the area of piston, and the number of strokes per minute. Hence the only way to increase the power of an engine is to increase either the M. E. P. or the number of strokes per minute.

(183) (*a*) How many different ways are there of telling whether the tubes in a surface condenser leak? (*b*) In a Putnam engine, how many ways are there of getting an equal and unequal cut-off? (*c*) In a Corliss engine, how can you make it cut-off at ½ on one end and more than ½ on the other? (*d*) In an old Rollins engine, what adjustments would you make to keep the engine from running away, if you were to leave it alone for a few minutes?

E. M. C., Onex, Mass.

ANS.—(*a*) There are four ways of detecting leaks in a surface condenser. (1) The steam space in the condenser may be filled with water and leaks detected by an examination of the tubes through the hand hole plates on the ends. (2) If the amount of feedwater in the hot well steadily increases, the presence of a leak is indicated. (3) Where the circulating water contains salt, as in sea water, and the condenser is leaking, a few drops of nitrate of silver in a glass of the feedwater will show a heavy, white precipitate. (4) A leak of any magnitude will always cause a fall in the temperature of the feedwater. (*b*) In the Putnam valve gear the port is opened by means of a cam pressing against the under side of a lever having a shoulder bend in it. This lever is attached to the valve stem. When the cam point comes to the shoulder, the lever, and with it the valve stem and valve, drops, thus closing the port. This lever extends at right angles to the shaft, and the point of cut-off can be varied by moving the lever out or in, thus causing the valve to be held open a longer or shorter period as desired. By adjusting the lever at each end of the cylinder, cut-off may be made equal or unequal as occasion may require. (*c*) Cut-off in a Corliss engine is caused by a projection on the trip collar disengaging the blocks and allowing the dash pots to close the valves. The position of this projection can be changed by rotating the trip collar about the axis of the valve; hence, lengthening the governor reach rods on one valve and shortening them on the other will change the cut-off as desired. If the load on the engine becomes so heavy that the governor moves the trip collar so far that it will not be struck by the hook before the reverse motion of the hook begins, release will not take place at all and steam is carried nearly full stroke. This reverse motion begins just before the piston reaches half stroke; consequently, it is impossible to cause cut-off to occur in a Corliss engine later than half stroke.

(*d*) The remedy for a racing engine is to increase the speed of the governor. By putting springs on the governor in such a manner that the balls are held down, almost any desired speed of the regulator may be obtained.

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(184) I have an ordinary fly ball governor. The engine is required to run at 65 revolutions per minute, but as the load varies the speed does the same, and when running goes up to 75. I increase the speed of the governor by putting a small pulley on the governor shaft and increase the tension of the spring to hold the engine down to 65 revolutions per minute unloaded, but still the speed varies. What would you advise me to do with it? H. H. Y., Trenton, N. J.

ANS.—Examine the governor and see that it does not have a tendency to stick at any point of its travel. If it is all right in this respect, it is probable that it does not run fast enough. A governor should run about 6 or 7 times as fast as the engine, or about 500 revolutions per minute. Increase the tension on the springs or put on heavier ones, speed the governor up, and we believe you will have no further trouble.

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(185) Please give me a rule for finding the amount of air entering a furnace from a blower; fan 6 feet diameter, revolutions 300 per minute, air duct 3 feet diameter, gauge shows 1 inch.

M. N. D., San Francisco, Cal.

ANS.—There are no data given for determining the mechanical efficiency of this fan, and the breadth of the fan is not stated. The manometrical efficiency, however, may be determined in the usual manner by finding the theoretical water gauge for this fan from the formula,

$$I = \frac{u^2}{g} \frac{1.2 \times 12}{1,000} \times 100; \qquad (1)$$

in which I = theoretical water guage (in);
u = tangential velocity of the blade tips (ft. per sec.);
g = force of gravity (32.16 ft. per sec.).

For a speed of 300 revolutions per minute the tangential velocity of this fan is

$$u = \frac{300\,(3.1416 \times 6)}{60} = 94.248 \text{ feet per sec.}$$

Then, substituting values in equation 1, we have $I = \frac{94.248^2}{32.16} \times 1.44 = 3.977$, say 4 in.

Then, for the manometrical efficiency, we have

$$K = \frac{i}{I} \times 100; \qquad (2)$$

in which K = manometrical efficiency of the fan;
I = theoretical water gauge (in.);
i = actual water gauge (in.).

Substituting values in equation 2, we have for the manometrical efficiency in this case,

$$K = \frac{1}{4} \times 100 = 25\%.$$

This is a low manometrical efficiency, which in the better types of fans approaches 50 per cent., and we may assume that the mechanical efficiency is likewise low, say, perhaps, 50 per cent. The formula for determining the yield of a fan, under all conditions, as given by Beard, is

$$Q = .0001 \left[\frac{K b n^2}{p \sqrt{a}} (D^3 - d^3) \frac{B \pm \frac{p}{70.6}}{459 + t} \right]^2; \qquad (3)$$

in which Q = quantity of air delivered (cu. ft. per min.);
K = mechanical efficiency of fan;
D = outer diameter of fan blades (ft.);
d = inner diameter of fan blades (ft.);
b = breadth of fan blades (ft.);
n = speed of fan (rev. per min.);
p = units of ventilating pressure (lb. per sq. ft.)
a = sectional area of fan drift (sq. ft.);
B = barometric pressure (in. of mercury);
t = temperature of air (Fahr.)

Then, assumiug $K = .50$, $D = 6$, $d = 4$, $b = 2$, $n = 300$, $p = 5.2$ (1 in. w. g.), $a = 36$, $B = 30$, $t = 60$, and substituting these values in equation 3, we have,

$$Q = .0001 \left[\frac{.5 \times 2 \times 300^2}{5.2 \sqrt{36}} (6^3 - 4^3) \frac{30 + \frac{5.2}{70.6}}{459 + 60} \right]^2$$
$$= 64,550 \text{ cu. ft. per min.}$$

In the above calculation such data as were not given have been assumed.

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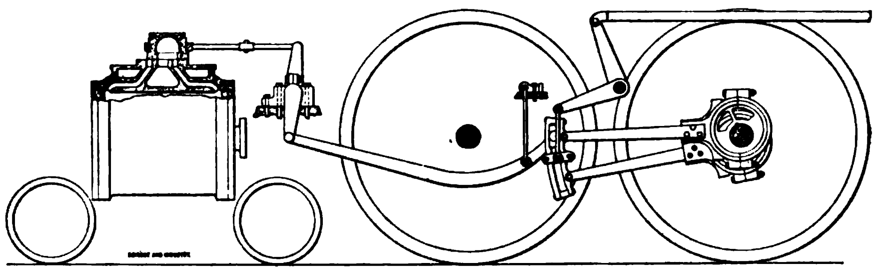
(186) (*a*) Please give sketch of cylinder and valve motion of Atlantic type of locomotives. (*b*) Why are indicator plugs placed in their steam chests, same as in their cylinders? (*c*) What would be the temperature, or pressure per square inch, at the end of their exhaust nozzles working steam at full stroke, boiler pressure 210 pounds per square inch? (*d*) Why is it that shut-off valves are not placed on the feedpipe of locomotives between boiler and check-valve as on stationary boilers? (*e*) Why are indicators not used more on locomotives than they are?

A. S., Tilbury, Ont.

ANS.—(*a*) A diagrammatical sketch of the cylinder and valve motion of an Atlantic type locomotive is given in the figure. This type of locomotive has four driving wheels, a four-wheel truck, and a pair of trailer wheels (the latter not shown in the figure). The eccentrics are placed on the second or main axle, and on that account it is necessary to employ a transmission bar to transmit the motion of the eccentrics past

the first driving axle to the valve rod. The rocker, therefore, is advanced forward of the first driving axle and connected to both the valve rod and the transmission bar. The back end of the transmission bar is suspended by means of a hanger, as shown. With these exceptions the valve motion is similar to that of a standard eight-wheeled locomotive. (*b*) Indicator plugs in the steam chests of Atlantic type engines are for the purpose of permitting the pressure in the steam chest to be indicated in order to determine what fluctuations of pressure take place with different speeds and for different positions of the reverse lever. In other words, they permit of an investigation of the fluctuations of steam-chest pressure, just as the plugs in the cylinders permit of an investigation of the fluctuations of the cylinder pressure. (*c*) We are unable to answer this, as the pressure, and therefore the temperature, depends upon too many variable quantities. (*d*) In locomotive practice globe valves are not placed in the injector delivery pipe between the boiler and the injector, for the reason that they are not necessary, and if used might be the cause of serious trouble. In locomotive service there is a boiler check-valve where the delivery pipe enters the boiler, and a line check in the injector itself, so that the two check-valves are considered sufficient. On some roads a third check-valve is sometimes placed midway between the other two, but a valve that must be opened and closed by hand is never used. Locomotive engineers already have so much to look after while on the road that there would be too great a chance of forgetting to open the valve after having closed it, and a serious accident might result. Also, there is danger of some one else closing it without the knowledge of the engineer, with disastrous results. (*e*) Indicators are now being used more and more every day on locomotives. The traveling engineers are now taking an active interest in the indicator, and excellent papers on "The Steam Indicator and Its Use" were presented at both the Cleveland meeting in 1900 and the Philadelphia meeting in 1901, of the Traveling Engineers' Association.



(187) Please explain how the Templet Odontograph is used to lay out the teeth of a gear when the pitch is less than 1 inch. In the book of instructions by S. W. Robinson, he gives the set for 1-inch pitch and says for any other pitch find the set from the table for 1-inch pitch and multiply by the pitch for the particular case. How can I find the set for a gear of less than 1-inch pitch? Please give examples.

J. R. B., Fredericksburg, Va.

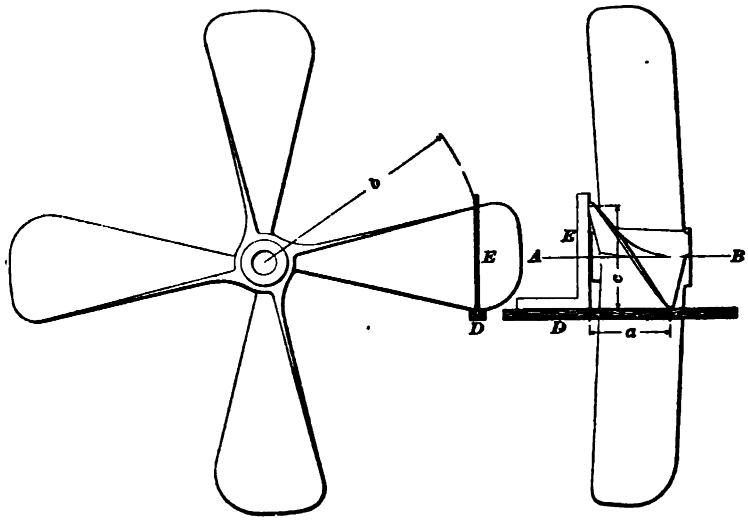
ANS. — The same method is followed, whether the pitch is greater or less than 1 inch. The setting for a gear of 1-inch pitch is obtained, and this value is multiplied by the pitch of the required gear. By referring to the table for "Sets" of Interchangeable Gears, we find that for a 20-tooth gear the setting for 1-inch pitch is .35 for face, and 1.95 for flank. For a gear of the same number of teeth and $1\frac{1}{2}$-inch pitch the settings would be, for face, $.35 \times 1\frac{1}{2} = .525$, and for flank, $1.95 \times 1\frac{1}{2} = 2.925$. For a gear of the same number of teeth and $\frac{3}{4}$-inch pitch the settings would be, for face, $.35 \times \frac{3}{4} = .2625$, and for flank, $1.95 \times \frac{3}{4} = 1.4625$.

(188) (*a*) Would you be kind enough to give directions for setting the valves of a duplex feed pump? (*b*) How is the pitch of the screw propeller found?

R. A. D., Montreal, Can.

ANS.—The steam valves of duplex pumps have no inside or outside lap, consequently when in their central position they just cover the steam ports leading to the opposite ends of the cylinders. With all these valves a certain amount of lost motion is provided between the jam nuts and the valve. This lost motion in small pumps is within the steam chest, while in large pumps it is outside, and may be adjusted while the pump is in motion. The first step fn the process of setting the valves of duplex pumps is to remove the steam-chest bonnets and place the pistons in their mid-stroke positions. To do this, open the drip cocks and move each piston by prying on the crosshead, but never on the valve lever, until it comes in contact with the cylinder head, and make a mark on the piston rod flush with the end of a stuffingbox gland. Move each piston back until it strikes the

opposite head, and then make a second mark on the piston rod. Half way between the first mark and the second make a third one. Then, if each piston is again moved until the last mark coincides with the face of the gland, the pistons will be exactly at their mid-positions. After placing the pistons in their mid-positions, set the valves central over the ports. Adjust the locknuts so as to allow about $\frac{1}{16}$ of an inch lost motion on each side. The best way of testing the equal division of the lost motion is to move each valve each way until it strikes the nuts, and see if the port openings are equal. When the port openings have been equalized the valves are set. The valve motion need not be and should not be disturbed while setting the valves. Too much lost motion lengthens the stroke and may cause the piston to strike the cylinder heads, while insufficient lost motion will shorten the stroke. The proper amount of lost motion to give a certain length of stroke can only be found by trial. If only one valve is to be set, it should be borne in mind that it is operated by the piston of the opposite side. (*b*) The principle underlying the method of determining the pitch of a propeller is simple proportion. First obtain the length of *part of the pitch;* then obtain the length of that *part of the circumference* that the propeller moves through as it advances the part of the pitch referred to above. We now have the proportion, part of circumference: whole circumference:: part of pitch: whole pitch. It now remains to obtain these measurements from the propeller. Referring to the cut, the straightedge D is placed so that it touches one of the blades at any distance, as b, from the center of the hub, and parallel to the shaft. Place a square as shown at E, so that it rests on the straightedge and also touches the other edge of the blade at the distance b from the center. Now, measure the distance a, b and c; a being the distance from the square to the point at which the straightedge touches the blade, and c being the distance from the point at which the square touches the blade to the straightedge. The distance a is *part of the pitch*. The distance c is that *part of a circumference* that the propeller would turn, in a solid medium to advance the distance a. This distance c is a part of a circumference having a radius b, consequently when we complete the above proportion we must take the whole circumference with the same radius. Solving the proportion we follow the rule that the product of the extremes equals the product of the means, or part of circumference × whole pitch = part of pitch × whole circumference. From this we get, whole pitch =



$$\frac{\text{part of pitch} \times \text{whole circumference}}{\text{part of circumference}} = \frac{a \times 2 \times 3.1416 \times b.}{c}$$

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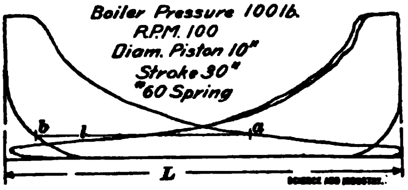
(189) From the accompanying indicator card and data, please answer the following questions: The boiler carries 100 pounds pressure, engine runs at 100 revolutions per minute, the diameter of the cylinder is 10 inches, and the stroke is 30 inches. A No. 60 spring was used in taking this card. We use a receiver above the engine, and of three times its capacity. The boiler is a high pressure 54″×16′, with thirty-four 4-inch tubes, and

the feedwater is heated by exhaust steam. (a) What should be the horsepower of the engine from which they are taken? (b) Does the card show that the engine is working economically, and if not, what remedies would you advise? (c) How many pounds of coal should be required per indicated horsepower per hour? (d) What is the



total steam consumption, and what is the steam consumption per indicated horsepower? (e) How many gallons of water would I have to pump into the boiler per minute to keep the water level? Part of the steam is used for the engine, and part for steaming wheat in a mill.

F. W. B., Bird Island, Minn.

Ans.—(a) By means of a planimeter, we find the area of each card to be 1.93 square inches and the length of the cards to be 4 inches, figure reduced to one-half size. Dividing the area by the length and multiplying the quotient by the scale of spring gives 28.95 pounds as the mean effective pressure. The area of the piston is 78.54 square inches, the length of stroke is 2½ feet, and the number of strokes is 200. Substituting these values in the well known formula I. H. P. $= \frac{plan}{33,000}$, we have 34.45 as the number of horsepower being developed at the time the cards were taken. (b) The cards are very satisfactory. The power developed in each end of the cylinder is the same and there is no back pressure above the atmospheric pressure. (c) The amount of coal used per horsepower per hour depends largely on its quality, but with ordinarily good coal from 1½ to 2½ pounds is a very fair average. (d) The steam consumption may be calculated from a card by choosing a point in the expansion line just before release and computing the volume of the cylinder and the absolute pressure of the steam up to this point. From the steam tables the weight of steam per cubic foot corresponding to the pressure may be obtained. Multiply this weight by the volume of the cylinder up to the chosen point and the result is the number of pounds of steam used per stroke. When it is desirable to consider the clearance, and there is sufficient compression shown in the card, the work may be simplified by taking two points a in the expansion curve and b in the compression curve at the same height above the vacuum line as shown in the accompanying cards. Since the absolute pressure at a and b is the same, the clearance is accounted for by taking the volume used in the computation as $\frac{l}{L}$ times the volume of the cylinder. When this method is used the steam consumption may be found directly from the following formula, $Q = \frac{13,750\,lW}{PL}$, in which Q is the number of pounds of steam used per horsepower per hour; W, the weight of a cubic foot of steam at the absolute pressure a; and P, the M. E. P. From the above card, we have $l = 2.2''$, $L = 4''$, the absolute pressure at a, 30 pounds and at $P = 28.95$ pounds. W, from the steam tables, is found to be .074. Substituting, we have $Q = \frac{13,750 \times 2.2 \times .074}{28.95 \times 4} = 19.33$ pounds of water per horsepower per hour. (e) The total number of gallons of feedwater required by the boiler per hour for engine purposes is $\frac{19.33 \times 34.45}{8.34} = 80$ gallons (nearly). Since it is not stated how much wheat is steamed it is impossible to make any estimate on the amount of water necessary for this purpose.

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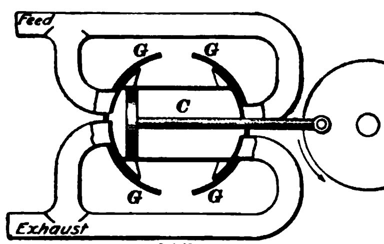
(190) Will the engine represented in the accompanying sketch work well as a model? The cylinder C moves around one way and then back again between the guides G G. There should be grooves in the latter to receive corresponding protusions on the ends of the cylinder for the purpose of keeping it well in place.

C. F. G., Rockingham, N. S.

Ans.—The engine shown in the sketch will run in the direction indicated. Since the port begins to open when the engine passes the center, it will not completely close until the



other center is reached and the cylinder is again brought to a horizontal position. It follows from this that steam will be carried full stroke and that therefore the engine is very uneconomical. It will, also, be difficult to maintain a steam-tight joint where the cylinder ends touch the frame.

ture and field is increased, and the meter speeds up until the torque is counterbalanced by the drag of the damping disk. In the shunt motor the speed is always such that the counter E. M. F. lets just sufficient current through to make the motor carry the load. An increase of field strength means that the motor does not have to run so fast to generate the counter E. M. F. If, however, the resistance were so high that it had a determining influence on the armature current as in the Thomson meter, the motor would speed up with increase in field strength. This condition of affairs would exist for efficiencies lower than 50 per cent., i. e., when the resistance drop in the armature is greater than the counter E. M. F. Of course, in practice, ordinary motors are always over 50 per cent. efficiency, so that this condition is not met with. As a motor, the efficiency of the Thomson meter is very small indeed; hence, the performance as explained above. (*b*) We do not know of any one book treating fully on all of the various kinds of wattmeters on the market. We would suggest that you send to the makers for descriptive catalogues.

***

(198) Referring to answer 272 in July, 1901, Science and Industry, and 64, of March, 1902, I have constructed a transformer as per answers. With 133 cycles it heats considerably and more so with 60 cycles. It also seems to use a large current with secondary circuit open. Kindly tell me if this can be remedied, and especially tell me what the winding should be for 60 cycles and also for 133 cycles, as I wish to make a transformer for each frequency.

C. D. O., Manlius, N. Y.

Ans.—The transformer referred to was intended for cautery work of an intermittent character. The transformer should not overheat with the windings given, though, of course, it will run warm, as nearly all small transformers do. The fact that your transformer takes a large current on open circuit, and thus heats considerably, would appear to indicate that either you have poor iron in the core, that it is not well annealed, or else the joints in the core are poor, thus making the magnetic reluctance of the core large. The windings given should work all right on 133 cycles if the core is all right. If, however, you have difficulty in securing good iron, it might be advisable to use 1,000 turns on the primary and 80 on the secondary. The transformer will, of course, heat more on 60 cycles on account of the larger magnetizing current required, so that for this frequency use 1,200 turns on the primary and 100 on the secondary. In order to get room for this winding, you may find it necessary to spread the cores a little farther apart.

MISCELLANEOUS

(199) What book on Calculus do you recommend as most suitable for a graduate of the Mechanical Engineering Course of the International Correspondence Schools?

J. E. M., Cincinnati, O.

Ans.—Differential and Integral Calculus, by P. A. Lambert, published by the Macmillan Co., New York, and Differential and Integral Calculus by George A. Osborne, published by Leach, Shewell & Sanborn, New York, are both excellent textbooks on this subject. They can both be obtained from the Technical Supply Co., Scranton, Pa.

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(200) (*a*) I want to heat the water in a tank 6 feet by 5 feet, containing 1,200 gallons, for a small plunge bath. I want to put a pipe coil in bottom of tank, and a grating on it to prevent burning the feet. I want to heat with live steam at 80 pounds pressure carried a distance of 80 feet through ½-inch pipe. Do you think it a practical and safe arrangement, and what size and quantity of pipe would you use for the coil? (*b*) The accompanying sketch shows a combination shower bath of 8 showers, also side view of one of them. We experience trouble from the bathers scalding themselves, and wish to know if you can suggest a remedy without using a mixing chamber. The steam is under greater pressure than the water. Would you use a smaller size of steam pipe or would you put a steam-pressure regulator or reducing valve in the present steam pipe?

J. M. O., Sioux City, Iowa.

Ans.—(*a*) The size of pipe coil will depend upon the time required to heat the water, the increase in temperature desired, also upon the overflow, if any. Assuming that you wish to heat the water from 40° to 100° in one hour without any changing of the water, then the number of square feet of heating surface required in the coil can be found by first determining the number of B. T. U. required to heat the water, then dividing it by 50,000, which is approximately the average number of B. T. U. given off by 1 square foot of the coil surface per hour. In your particular case,

$$\frac{1{,}200 \text{ gals.} \times 8.25 \text{ lb.} \times 60° \text{ F.}}{50{,}000 \text{ B. T. U.}} = 12 \text{ sq. ft.}$$

of coil nearly. A half-inch pipe is too small to do this work properly. We think you should make the coil of at least 1 inch pipe. (*b*) You should use a mixing chamber, attaching a sensitive thermometer in the chamber in such a manner that the temperature of the water in the chamber shall be indicated to the bather. Otherwise you

cannot properly regulate the temperature of the shower. The shower shown in your sketch is too dangerous to remain in use.

***

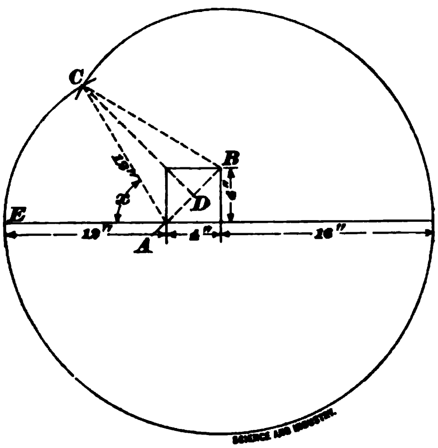
(201) (*a*) Give an explanation of the error that arises in the following:

Let	$x = a;$	(1)
Multiplying by x,	$x^2 = a\,x;$	(2)
Subtracting a^2,	$x^2 - a^2 = a\,x - a^2;$	(3)
Factoring,	$(x-a)(x+a) = a\,(x-a);$	(4)
Dividing by $x-a$,	$x + a = a;$	(5)
Substituting a for x,	$a + a = a;$	(6)
Whence,	$2 = 1.$	(7)

(*b*) Find the angle marked x in the figure.

W. H. C., Chicago, Ill.

ANS.—(*a*) When a given equation is multiplied or divided by 0, or an expression containing the unknown number, the resulting equation is not equivalent to the given equation; that is, the resulting equation does not necessarily have the same roots as the given equation. Now (2) is obtained from (1) by multiplying (1) by x, and by solving (2) the values 0 and a are found for x. Thus, it is seen that the root 0 is inserted in (2). By solving (5) this root is again taken out. Again, to divide (4) by $x - a$ is to take out the root $x = a$; that is, (5) is not equivalent to (4). The value $x = a$, the true root of equation (1), can be obtained the second time by setting the factor of (4), $x - a$ equal to zero. In solving an equation, the root or roots found should be tested by substituting them in the given equation and



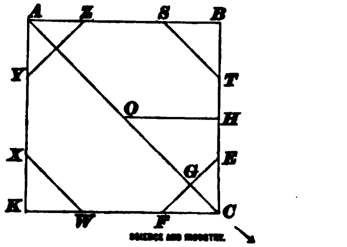
seeing that they satisfy it. Thus, solving (5), $x = 0$, and substituting 0 for x in (1) does not satisfy (1); so that if (1) is true, (5) is not true and a cannot be substituted for x. (*b*) From the figure $A\,B = 4\sqrt{2}$ and $D\,B = 2\sqrt{2}$. Hence, $\sin B\,C\,D = \frac{2\sqrt{2}}{12}$, or $\frac{\sqrt{2}}{6}$. That is, $\sin B\,C\,D = .23571$. From table of natural sines, $\angle B\,C\,D = 13°\ 28'$. Again, from figure, $\angle C\,B\,D = 90° - 13°\ 38' = \angle C\,A\,D$. Also, $\angle D\,A\,E = 135°$. Hence, $\angle x = \angle C\,A\,E = \angle D\,A\,E - \angle C\,A\,D = 135° - (90° - 13°\ 38') = 58°\ 38'$. Ans.

***

(202) The side of a square is 40 yards. What is the side and area of the largest regular octagon that can be inscribed in it?

H. F., Carmen, Manitoba.

ANS.—Let $A\,B\,C\,K$ be the given square and $E\,F$ one side of the required octagon.



Draw the diagonal $A\,C$. Then, $G\,F = G\,C = O\,C - O\,G$. But $O\,C$ is one-half D, the diagonal of the square; and $O\,G$ is equal to $O\,H$, which is equal to one-half S, the side of the square. Hence, $2\ G\,F = 2\,(OC - O\,G) = D - S$. Now, if one-half D is measured off from C toward B, and one-half D is measured off from B toward C, the distance between the points thus found is $S - 2\,(S - \tfrac{1}{2}D)$, or $D - S$. Hence, to lay off the largest regular octagon in the square $A\,B\,C\,K$, with a line equal to one-half the diagonal $A\,C$, begin at A and measure off $A\,S$, $B\,E$, $C\,W$, and $K\,Y$; then, with the same line, lay off $A\,X$, $K\,F$, $C\,T$, and $B\,Z$. The points Z, S, T, E, F, W, X, and Y are the vertexes of the required octagon. When the side of the square is 40 yards, the diagonal is 56.57 yards. Hence, the side of the octagon is $56.57 - 40$, or 16.57 yards. The area is $8 \times \tfrac{1}{2} \times 20 \times 16.57$, or 1325.6 square yards.

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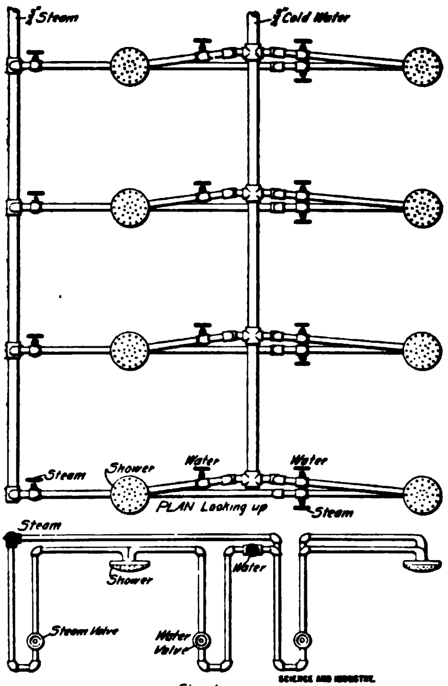
(203) (*a*) Where can I obtain a good book on the designing of machinery? (*b*) Please give me the correct formula of a catenary which a wire rope forms, the two supports on which it is suspended having the same elevation; also, when the supports are of different elevations. (*c*) Please explain the term "radius of gyration."

A. A. L., St. Louis, Mo.

ANS.—(*a*) Apply to the Technical Supply Co., Scranton, Pa. (*b*) The catenary is the form assumed by an inelastic chain of uniform density when suspended freely between two points. Its equation is $y = \frac{a}{2}\left(e^{\frac{x}{a}} + e^{-\frac{x}{a}}\right)$. The constant a is the dis-

tance from the origin to the vertex of the curve. The equation of the curve is the same whether the supports are at the same or different elevations. (*c*) Suppose that a body is free to move about an axis or to oscillate like a pendulum, and that a force is applied to the body at a certain distance from the axis or point of suspension, so as to cause the body to revolve or oscillate through a certain number of degrees per second. Now there is a point in the body such that if the entire mass of the body were concentrated at this point, and if the same force were applied at the same distance from the axis or point of suspension as before, the body would describe the same number of degrees per



second. This point is the *center of gyration*, and its distance from the axis or point of suspension is the *radius of gyration*. Thus, for a body, the radius of gyration about an axis is that length whose square is the mean of all the squares of the distances, of the indefinitely small masses that make up the body, and its square is found by dividing the moment of inertia by the mass. That is, if k is the radius of gyration, I the moment of inertia, and M the mass, then $k^2 = \frac{I}{M}$. To illustrate, the moment of inertia of a cylinder of radius R and mass M about its axis is $\frac{MR^2}{2}$. Hence, $k^2 = \frac{MR^2}{2} \div M = \frac{R^2}{2}$; or, $k = \frac{R}{\sqrt{2}}$. That is, the radius of gyration of a cylinder about its axis is equal to the radius of the cylinder divided by $\sqrt{2}$.

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(204) Please recommend some books on the locomotive and air brake, which treat the subjects thoroughly, and which a fireman can understand.

C. H. J., Middletown, N. Y.

ANS.—"Locomotive Mechanism and Engineering," by H. C. Reagan, price $2, is a first-rate book on locomotives. For air brakes consult "Air-Brake Catechism," by Robert H. Blackall, price $1.50. These books can both be procured from the Technical Supply Co., Scranton, Pa. If you wish a thorough understanding of these subjects, we should strongly advise you to take a Course in the International Correspondence Schools. They give Courses in these subjects, which cover the ground very thoroughly, and from which you can obtain a very much better understanding than by trying to study them by yourself.

***

(205) (*a*) What is meant by the angle of advance? (*b*) What is meant by the throw of the eccentric? (*c*) If you have 80 pounds steam pressure in a boiler, is there any difference in the pressure above the water and below it? F. J., Grafton, O.

ANS.—(*a*) By the angle of advance is meant the amount the eccentric is set ahead of a line at right angles with the crank. It is the lap angle + the lead angle. (*b*) The throw of the eccentric is the distance between the center of the eccentric and the center of the shaft which carries it. (*c*) Steam in a boiler under pressure of 80 pounds, exerts the same pressure in all directions, so that the pressure below the water is the same as that above it, not taking into account the weight of the water itself, which, of course, exerts some pressure.

***

(206) Please explain with an example how to design a band brake, a shoe brake, and a shaft. H. M. K., Lexington, N. C.

ANS.—It would take more space than we can devote here to give this information, and it would be necessary to have a thorough understanding of elementary machine design in order to understand the explanation. We should advise you to secure some good book on machine design, and study it, or, better still, to take a Course in Mechanical Engineering in the International Correspondence Schools. This Course thoroughly covers the subjects on which you wish information, besides a great deal more.

SCIENCE AND INDUSTRY

Vol. VII August, 1902 No. 8

USING EXHAUST STEAM ADVANTAGEOUSLY

BY W. H. WAKEMAN

IN one of the first plants that I had charge of, there was an old cylinder boiler set on the top of a large brick pier, which raised it above the tubular boiler used to generate steam. See Fig. 1. Water was pumped into this old boiler, which was then called a tank, from a driven well, and as the top of it was about level with the eaves, it supplied water to the three floors of the mill in which it was located.

The exhaust pipe of the engine was tapped into the side of the tank near the bottom, as shown, then turned upwards, passing through the body of water, and then through the roof to the air. This heated the water and made a very convenient arrangement. Near the top there was an overflow pipe which discharged onto the one-story engine room roof, thus giving information concerning the amount of water in the tank. As heat from the exhaust steam was imparted to the water, condensation resulted, which could not be disposed of properly, owing to the conditions under which it was formed.

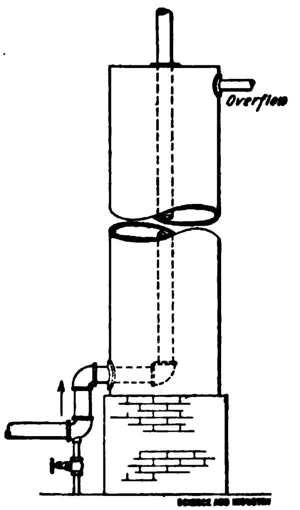

FIG. 1

The drip pipe shown carried off nearly all of the water, when there was only a light load on the engine, as it would find its way down through the large exhaust pipe against the steam traveling upward. When a heavy load was thrown onto the engine, causing a large volume of exhaust steam to be discharged, water was thrown out of the exhaust pipe in showers, which drenched everything in the vicinity.

The result of this so far as the engine was concerned, was to add several pounds back pressure, when it worked to the greatest disadvantage. By adopting the arrangement of piping shown in Fig. 2, back pressure from the condensation of steam could be avoided, as the course of steam in such a case is downward, and whatever water results assists the steam to escape rather than hinders it, as in the first case mentioned. At the time of which I write, exhaust steam was seldom considered valuable, so that the above mentioned plan was a novelty.

In the next plant that I was placed

in charge of, much live steam was used for heating water, drying cloth, and warming the several rooms in cold weather. The exhaust steam passed

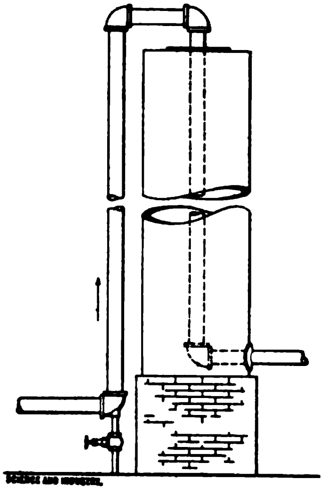

FIG. 2

through a feedwater heater, where a portion of it was utilized, but the remainder passed directly into the air and was wasted.

Fig. 3 shows the arrangement of piping in another mill. The exhaust pipe, as it comes from the engine and discharges into the heater, is 8 inches in diameter. Leaving the heater it passes through a dead-weight back pressure valve, and a free exhaust pipe that is not reduced in size, to the air. During warm weather the back-pressure valve *2* was raised so as to allow steam to escape freely, but when cold weather came it was lowered into place and the gate valve *3* opened, but this was only 6 inches in diameter, thus reducing the area of opening provided for the escape of steam from 50 to 28 square inches. A few yards from this valve a 3-inch outlet was provided for conducting steam to several coils of smaller pipe. Beyond this the 6-inch pipe was reduced to 3 inches, thus still further reducing the area of outlet, bringing it down to two 3-inch pipes, or 14 square inches, which is 28 per cent. of the full exhaust opening provided. In order to be on the safe side it is well to continue an exhaust pipe full size until there is enough surface exposed to condense considerable of the steam, when the pipe may be reduced accordingly. Let us estimate this in the foregoing case. When the pump is forcing enough water through the heater to maintain a constant water level in the boilers, and steam is used for the sole purpose of running an engine, to raise the feedwater from 50° to 212° will condense about 17 per cent. of the exhaust steam; therefore, the outlet from the heater may be made 17 per cent. smaller than the inlet. This calls for a pipe 7⅝ inches in diameter, but as that size is not made, it is necessary to use an 8-inch pipe.

If a liberal allowance is made for condensation after leaving the heater, the

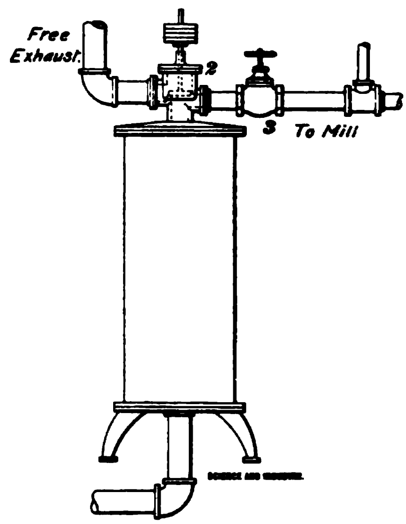

FIG. 3

outlet to the mill may be made 7 inches, and the two outlets beyond the valve *3* may be 5 inches each, giving more than

38 square inches area instead of 14, as it now stands.

The practical operation of the arrangement of piping illustrated is as follows: Unnecessary back pressure is put on the engine because the steam cannot escape through the small openings provided in the mill; therefore, the back pressure valve *2* is nearly always open, allowing steam to escape to the air.

The two 3-inch pipes are not large enough to supply all of the radiators; therefore, some parts of the mill are not heated enough to be comfortable.

The back-pressure valve *2* is very old-fashioned, as there are no levers on it, but heavy weights exert a direct pressure. The gate valve *3* is also of an old-fashioned type, as it requires 31 turns of the wheel to open it.

Another plant is fitted with a 6-inch pipe from the engine to the end of the heating system. All of the exhaust steam can be forced through this pipe without creating one pound back pressure. This is an ideal arrangement so far as avoiding the unnecessary development of power is concerned, and that is an important factor.

Fig. 4 illustrates a plan that was adopted for heating water in a tank. The exhaust pipe at the engine is 8 inches in diameter, and is continued for a short distance when it is reduced to 6 inches, and carried 25 feet horizontally. It is then reduced to 4 inches and raised 8 feet, as shown, after which it goes into a tank 30 feet long, full of water. There is nearly 200 feet in length of this 4-inch pipe, the end rising above the tank and discharging into the air. A drip pipe at *2* discharges water into the tank so as to prevent waste. When first erected there was no drip from the coil, so that all of the water had to be lifted out of the tank. When we consider that 27.7 inches in height of water causes one pound pressure, and that every pound back pressure on this engine represents 5 horsepower, we can see how wasteful the plan is.

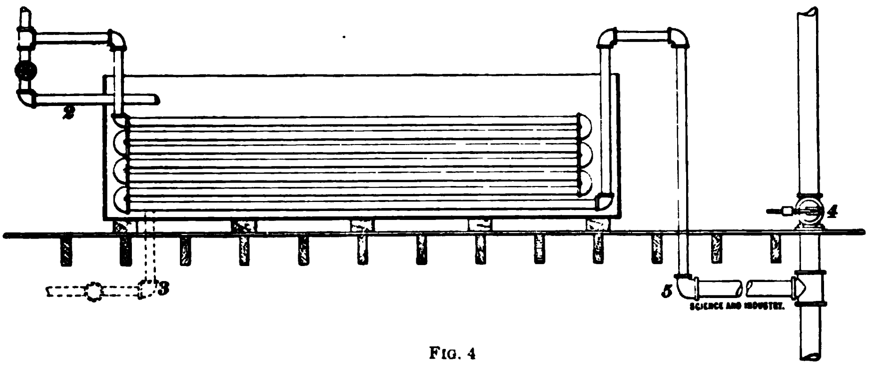

Fig. 4

There was a back-pressure valve at *4* when the plant was erected, but it was taken out and used elsewhere. A cap was screwed on the end of the exhaust pipe, and this in connection with the badly arranged coil in the tank made a back pressure of 8 pounds on the engine, requiring 40 horsepower to overcome it.

As this proved objectionable, the exhaust pipe was given a fixed opening 3½ inches in diameter, and a drip made of 1¼-inch pipe put in to relieve the coil at *3*, which discharged its full capacity at given pressure, showing that it was not too large. These changes

reduced the back pressure, but it was still higher than good practice admits.

In the foregoing illustration a coil is shown in the tank that resembles a heating coil on one side of a room, but it was drawn in this way for convenience only, as the coil is located on the bottom of the tank. This engine was heavily loaded, therefore the piping ought to be arranged so as to prevent back pressure as far as possible. The exhaust pipe ought to have been 8 inches to the ell at *5*, after which 7-inch pipe would

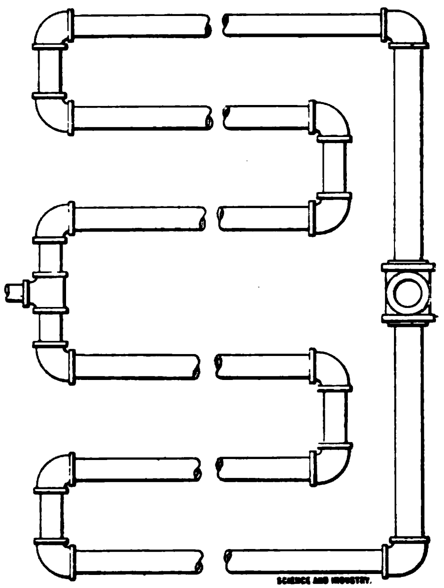

FIG. 5

answer until the bottom of tank was reached. This reduction might be permitted in order to save the cost of large pipe, because a feedwater heater condenses about 25 per cent. of the steam coming from the engine. Inasmuch as large quantities of live steam are used for heating purposes, much of the exhaust steam is required for heating the feedwater.

The 7-inch pipe should enter the tank at the top and be continued to the bottom, where it enters a tee with 5-inch outlets, as shown in Fig. 5. These two are equal to the 7-inch inlet, so there is no contraction of area at this point. On the end of each 5-inch pipe there is a reducing ell 5×4 inches, which means a smaller area here, but condensation is rapidly reducing the volume of steam, for it must be remembered that Fig. 5 is a plan of the piping, showing it as it appears when viewed by looking down into the tank, consequently all of these fittings are under water.

After as many lengths of pipe as are required are laid in the bottom of tank, the two pipes may be joined together, as shown, in order to avoid the necessity of making two outlets through the side of tank. By bringing the inlet pipe up over the top, and placing the outlet at the bottom, as shown, expansion and contraction of the pipes are provided for without further trouble, and one 4-inch outlet is large enough for the water to escape through.

When this plan is put into use all of the exhaust steam may be used for heating water without adding 1 pound of back pressure to the engine. I wish to call attention to the two plans here presented for putting the water resulting from condensation back into the tank. In Fig. 4, raising it to top of tank and allowing it to flow back through the drip pipe *2*, causes a back pressure of 3 pounds on the engine piston, which has an area of 314 square inches, while in carrying out the plan shown in Fig. 5 a pump would be employed to put the water back, thus creating a pressure of 3 pounds on a piston having an area of 28 square inches. One is more than 11 times as large as the other, and the difference in power is in the same proportion.

When considering a proposition of this kind the following question always arises in some form, "Does it pay?"

In the case just mentioned it cer-

tainly did not pay to use it, because the engine was overloaded to an extent that prevented it from doing the required work. I state the case in this way because opinions differ concerning what is meant by an overloaded engine, but when a load is put on that shuts an engine down with the highest pressure allowed on the boiler there is little chance for a misunderstanding concerning it. The addition of a few pounds back pressure does not always have this effect, however, and in such a case the problem appears in a different light, as follows:

Assuming that when an engine is carrying its full load, the cut-off takes place at ¼ stroke, with a free exhaust, adding 3 or 4 pounds back pressure causes the point of cut-off to be lengthened, which means that more steam is taken from the boilers. Now the point to be decided is whether this extra steam is used to good advantage or not. If all of the exhaust steam is used and live steam must be taken to get heat enough to secure desired results, then there is no loss caused by adding back pressure.

On the other hand, if only a portion of the exhaust steam is used, and it is necessary to add back pressure in order to do it, then it may be unprofitable, but careful investigation of the conditions in each case can alone decide the point.

It is perfectly safe to say that in a large majority of cases where back pressure exists, it is due to defective arrangement of piping rather than to conditions which cannot be improved, yet some owners seem to think that the best possible plans have been adopted in their plants, and that the costly back pressure is a necessary evil.

FUEL ECONOMY

GEORGE E. WALSH

ECONOMIZING in fuel is a part of the engineer's work, and his worth should be valued somewhat according to his ability to handle a steam plant so that the maximum of efficiency can be obtained therefrom at the lowest possible cost for fuel. That there is all the difference in the world between engineers and firemen is testified to by a comparison of the coal bills of different plants which practically require the same amount of horsepower. The fireman and engineer who understands the principles of firing and generating steam according to the very latest methods may well save to his employers the full amount of his salary.

But there is a limit to the efficiency of the operators of a steam plant. Economy carried too far may prove a false saving, for anything that reduces the efficiency of the plant more than compensates for the saving of any waste of fuel or heat. Machines to economize in the use of fuel have rapidly become important features of modern steam plants, and while they have been used for many years in England, they have not until recently received the attention they deserve in this country. One reason for this has been the abundant supply of coal, which has made Americans prodigal and wasteful in its use.

One of the pioneer workers in studying methods to economize in fuel was Mr. Edward Green, of England, who more than half a century ago invented an attachment to utilize the waste heat of a steam plant. Since then steady improvements have been made by

different inventors. One of the first steam plants in this country to experiment with fuel economizers was the large print works of Thomas Saunders at Providence, Rhode Island. Before that fuel economizers had been exhibited at the Philadelphia Centennial, but they had attracted comparatively little attention.

Several large sugar refineries were installed with fuel economizers a few years later. Some of these patents were brought from England and Germany, and then improved upon in this country. In their whole evolution the various types of fuel economizers have steadily advanced toward a certain standard of pattern which is in general use today. The various types differ somewhat in detail and operation, and the question of their relative efficiency is one that must be decided by actual test and experiment. A good many of the electric-light companies and steam-heating plants today have had different fuel economizers constructed. Ten years ago it was necessary to import all of the machinery of this character from abroad, but its manufacture today in this country is quite general, and on an ever increasing scale. Consequently, the fireman and engineer should become as familiar with their use and operation as with any other part of a plant.

The standard type of fuel economizer bases its utility upon the simple principle of utilizing the waste heat of the boiler which escapes up the chimney. It requires no restatement of figures and tests to familiarize any student with the fact that the waste of heat up the chimney is enormous, and the question of utilizing it all in generating power has been one that has attracted engineers and scientists for years. The world of invention is full of schemes and suggestions for increasing the combustion of coal so that more of its heat could be used, but none of them have yet succeeded in eliminating the waste entirely. It is doubtful if we can ever invent any furnace, flue, or boiler which will enable a fireman to convert all of the heat units of a pound of coal into power.

But the modern fuel economizer essays to utilize some of the waste heat as it escapes up the chimney. This is obtained by building a stack of tubes in the flue leading from the boiler to the chimney. These tubes are placed in a vertical position so that as the escaping hot air, smoke, and gases pass from around and through the boiler they come in contact with the auxiliary set of boiler tubes. The feedwater of the boiler first passes through these auxiliary tubes, and the waste heat and gases, though at a low temperature compared with that of the boiler, raise the temperature of the feedwater so that when it enters the boiler tubes proper it is near or quite the boiling point. It is necessary to pump the water through these additional boiler tubes in some instances, but the saving of heat necessary to raise the water to the boiling point when it enters the boiler tubes is quite great.

This was the principle on which the first English inventor made his tests, and modern inventors have merely modified and improved upon his early apparatus. The location of the vertical tubes between the boiler and chimney requires a nice sense of proportion on the part of the builder, for it is necessary that all the waste heat and gases should pass through the sets of tubes to heat them. At the same time this must be accomplished without interfering with the draft of the chimney.

One of the early difficulties found

with the fuel economizers was that the sulphur in the gases wrought such great changes in the tubes that they quickly degenerated. Steel and wrought iron were in time abolished, and the tubes are now made of cast iron, but sufficiently strong to resist the boiler pressure of the steam. As a result the auxiliary tubes maintain their efficiency for as great a length of time as the ordinary boiler tubes.

Another difficulty was caused by the clogging of the tubes by the smoke, soot, and gases, which in a short time made it almost impossible for the fire to draw through the chimney. Repeated cleaning of the flue was found necessary. This was not especially inconvenient in plants where steam was shut down once a week, but where the fires were rarely allowed to die out it caused delay and expense which more than offset the gain. Consequently, automatic cleaning attachments were invented, and these are continuously at work removing the soot and dirt from the tubes. The scraping or cleaning device consists simply of cast-iron sockets fitted in rows to the tubes. They are all fastened together, and so snugly that as they move up and down the whole length of the tubes they scrape everything from them. This invention has removed one of the worst difficulties in the way of a general adoption of the fuel economizers. The tubes can always be kept clean. An opening to remove the soot and smoke scraped from the tubes further simplifies the work.

The increase in the efficiency of a boiler with such fuel economizing attachments ranges all the way from ten to twenty per cent. A good deal depends upon the construction of the boiler and chimney. The draft of the chimney is also an important consideration. Anything that will interfere with that naturally counterbalances any gain that may be made in the fuel economizers. The engineer in charge of building the works, and in making the attachment, must be largely responsible for the success of the new scheme.

BLAST FURNACE GAS ENGINES

SOME interesting experiments have recently been made in Europe with internal combustion engines using the gases derived from blast furnaces. The first trials were made in Europe in 1894, and by 1900 a machine of 750 horsepower was exhibited at the Paris exposition. The average heating power of blast-furnace gas is 980 calories per cubic meter. In the majority of the engines the compression before ignition runs up to from 120 to 135 pounds, and without ignition the cylinder pressure is as high as 240 pounds. The indicated horsepower output amounts to a little over thirty per cent. of the theoretically possible total, the losses being twenty-four per cent., carried off in the cooling water surrounding the cylinders and forty-six per cent. in the gases. A fifty-horsepower motor has been brought up to a consumption of 1.4 cubic meters per kilowatt hour. About thirty-five gallons of water per hour for cooling are required for each horsepower, while one pound of grease or oil per hour for twenty horsepower is the average consumption of lubricant. The furnace gases contain, on an average, about four grains of dust per cubic foot, of which about three grains arc deposited very easily before reaching the engine, and nine-tenths of the balance is stopped in the purifiers.

USEFUL FORMULAS—VII

BY JOSEPH E. LEWIS, S. B.

HYDRAULIC HEAD, $p = 0.434\ h$

WATER pressure is usually not so easily understood by the average person as steam or air pressure. The two sorts of pressure may affect the gauge in much the same way, but their causes and nature are quite different. The reason and explanation of this is found in the fact that water and steam have very different physical properties. Steam is compressible, while water is incompressible. Steam exerts pressure because it is compressed and confined within a limited space; water exerts pressure because of its own weight, or because of the weight or force of some outside agency acting upon it. Gases and vapors differ from liquids in that they are elastic and are always seeking to expand against any force holding them in confinement. The small particles or molecules of which the gas is composed seem to repel each other; they have a tendency to remain as far apart as possible; while in a liquid the tendency seems to be directly the opposite, that is, the molecules attract each other and remain as close together as possible. That is the reason why a liquid cannot be compressed while a gas can be, and that is why a liquid exerts no expansive pressure while a gas does.

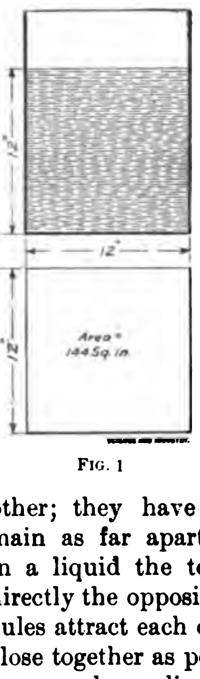

FIG. 1

Now, all gases may be changed to liquids by cold and pressure. This statement was formerly only a theory, pretty well grounded perhaps, but still not actually demonstrated. Today it may be regarded as a statement of fact. A very striking illustration of this fact is seen in the remarkable achievements of Mr. Trippler in liquefying air. This had, of course, been accomplished before as a laboratory experiment, but Mr. Trippler's work, on what may be called a commercial scale, brought the subject more strongly into public notice. Now in just the same way that cold and pressure change a gas into a liquid, so do heat and the absence of pressure change a liquid into a gas. Just what goes on when heat is applied to a liquid, say water for example, no one can say. We know that the heat is absorbed and that the water turns to steam. We say that the heat has become latent, which means that it has ceased to be heat in its usual form, and has become some other kind of energy which has given to the molecules of the water a certain activity causing them to repel each other, giving rise to the force of expansion. This tendency to expand causes pressure when we confine the steam in a limited space.

Now the pressure of water is very different. Since it cannot be compressed it cannot exert any expansive force. Its pressure is due to the force of gravity or to some external mechanical force acting upon it when confined; as, for example, the plunger of a pump, or the ram of a hydraulic press or accumulator. Disregarding for the moment these latter mechanical causes, let us consider the natural cause of water pressure and the laws of its action. In Fig. 1 we have a vessel nearly full of water. We will say that the base of the vessel is just 1 square

foot in area and that the water stands a foot high. Then we have 1 cubic foot of water weighing about $62\frac{1}{2}$ pounds. Now it is easy to see that the total pressure on the bottom of the vessel is $62\frac{1}{2}$ pounds, which is equal to $\frac{62\frac{1}{2}}{144} = 0.434$ pounds per square inch.

In Fig. 2 we have a vessel of another form the area of whose base is still 1 square foot, but the area at the top is only about half as much. The water stands 1 foot high as before, but there is less than 1 cubic foot of water. We will say that the vessel is so much cut away at the top that only $\frac{2}{3}$ of a cubic foot or 41.7 pounds of water are present. Now the total pressure on the bottom will be the same as in Fig. 1, despite the fact that there is only two-thirds as much water present. This pressure will be $62\frac{1}{2}$ pounds, or 0.434 pounds per square inch, as before. If this is not perfectly clear at first thought, a little consideration should make it evident. You can readily see that the pressure within the dotted area is 0.434 pounds per square inch, because a column of water 1 inch square and 1 foot high rests on each square inch of this space. Now, outside of the dotted area we have a column of water 1 inch square and 6 inches high above every square inch of the bottom. The pressure due to the weight of this column is 0.217 pounds per square inch or one-half of 0.434. Now the top of each of the columns is pressing against the top of the vessel. To prove this, make a small hole and the water will spurt out, or if you insert a little tube, as at A, the water will "seek its own level." Then the pressure on this top partition is due to the height of the water in the open part of the vessel, and since this is 6 inches high the effect is the same as if the sides of the vessel were straight and the water stood a foot high, as in Fig. 1. That is to say, the pressure on the top is 0.217 pounds per square inch, and this pressure is balanced by an equal pressure at the bottom; that is to say, if the water presses upward against the top partition, it must also press downward with the same force directly under the partition.

To this must be added the actual weight of the water, or 0.217 pounds per square inch, making the total pressure 0.434 pounds per square inch outside of the dotted area as well as within.

We started out by saying that water pressure is due to the weight of the water, and in a general way this is true, but the foregoing illustration should make it plain that something else besides weight must be considered, namely, height. It is not the quantity of water present that determines the pressure. The pressure is the same in both Fig. 1 and Fig. 2, although there is less water in the second case than in the first. But the height of the water is the same in each case, and therefore the pressure is the same. Take Fig. 3, for example. Here we have, say, one-tenth as much water as in Fig. 1, and yet the pressure on the bottom of the vessel is the same as before, namely, $62\frac{1}{2}$ pounds or 0.434 pounds to the square inch.

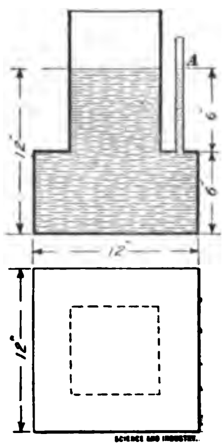

FIG. 2

We cannot fix it too firmly in our minds that it is the height of the water level which determines the pressure

upon any submerged surface. It would perhaps be more correct to say that the pressure upon any submerged surface depends upon two things; namely, the weight of the liquid and the height of the free surface. We must rid our minds of the idea that the *quantity* of liquid present has anything to do with it. This is sometimes called the "hydrostatic paradox."

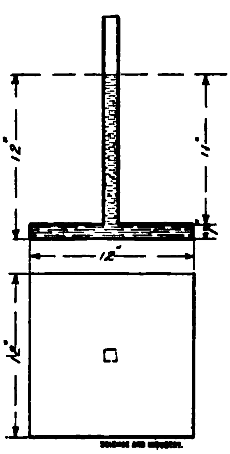

FIG. 3

Now the height of the free surface of the water, or the water level, is technically called the hydraulic or hydrostatic head, and the pressure due to the head is computed by the very simple formula, $p = 0.434\ h$ or $h = 2.3\ p$, in which p equals pressure in pounds per square inch, and h equals the head in feet, that is, the vertical height of the free water surface above the submerged surface in question. We have already demonstrated the truth of this formula when we showed that with the water level 1 foot high the pressure was 0.434 pounds per square inch whatever the shape of the vessel or the quantity of water present.

The same principle applies to all liquids, but the numerical values in the formula depend upon the weight of the liquid, and are given above only for water. They would be different for any other liquid; for instance, for mercury, the formula would be $p = 5.9\ h$, or $h = 0.0169\ p$, and for olive oil, $p = 0.399$ and $h = 2.51\ p$.

Since a mercury column is commonly used to measure small pressures, a few words on this subject in passing will not be out of place. The weight of the atmosphere at sea level is about 14.7 pounds per square inch, and this pressure will balance a column of mercury very nearly 30 inches high. For ordinary engineering work it is accurate enough to say that a pressure of 15 pounds supports 30 inches of mercury. Then, 2 inches represents a pound and $\frac{1}{8}$ of an inch represents an ounce. Fig. 4 illustrates a crude apparatus which any one can make in an hour and which the writer has frequently used in experimental work to excellent advantage. Occasion has frequently arisen in experimental work on tests of one sort or another to measure pressures or differences of pressure which the ordinary steam gauge will not record with any accuracy, and for which the indicator cannot be well applied. This little mercury gauge has given excellent results in such cases since it indicates pressures as small as 1 ounce and since it will measure vacuums as well as pressures.

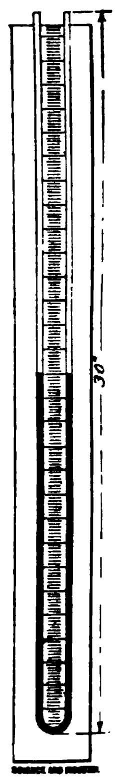

FIG. 4

Any engineer can make one for himself by securing a piece of glass tubing about $\frac{1}{4}$ inch outside diameter and $\frac{1}{8}$ inch or so inside diameter, at a chemical supply house. The tube should be 4 or 5 feet long, so that each leg will be 25 or 30 inches long when bent. To bend, hold the tube in an ordinary gas jet. Heat slowly and bend gradually so as not to flatten the tube. The **U** tube should now be mounted upon a board upon which has been marked off a scale reading in inches and eighths of

inches. Pour in mercury until each leg is half full. For measuring a pressure connect one leg with the vessel under pressure by means of a rubber tube. A pressure will cause a difference in levels one way, a vacuum the other way, as will be readily understood. In reading remember that it is $\frac{1}{8}$ of an inch to the ounce. For measuring differences of pressure connect one pressure to one side and one to the other.

So far we have considered only the pressure on the bottom of a vessel; what about the pressure on the sides? We can best answer this by stating a general rule, which is as follows: The pressure on any submerged surface is equal to the area of the surface in square inches multiplied by the pressure per square inch at its center of gravity, which for a plane figure will be its geometrical center; and the pressure at the center is, of course, determined by our formula, $p = 0.434\ h$. Remember this rule, and you can figure the hydrostatic pressure on any surface, no matter what its shape, size, or location. Take an example for illustration:

What is the total pressure on the surface A in Fig. 5, assuming it to be 3 feet square?

Solution:

$$h = 12';$$
$$p = 0.434 \times 12 = 5.208;$$
$$\text{Area} = 3 \times 3 = 9;$$
$$9 \times 5.208 = 46.872 \text{ lb. Ans.}$$

Find the total pressure on the sphere B, Fig. 5.

Solution:

$$h = 11;$$
$$p = 11 \times 0.434 = 4.774;$$
$$\text{Area} = \pi D^2 = 3.142 \times 9 = 28.278;$$
$$28.278 \times 4.774 = 134.89 \text{ pounds. Ans.}$$

As previously stated, hydrostatic pressure may result from some mechanical force acting upon water in a confined space, as, for example, by pumping. It should be borne in mind that water always has a pressure due to its own head irrespective of any outside pressure imposed upon it. It will be sufficient to say that this outside pressure is transmitted undiminished throughout the whole system. It must be corrected, however, by adding to it the pressure due to the hydrostatic head at any point to find the total effective pressure at that point.

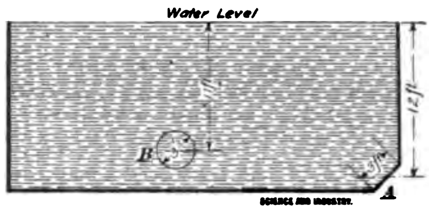

FIG. 5

SOME GAS-ENGINE DON'TS

DON'T use cheap cylinder oil or steam-engine oil on your engine.

Don't fail to oil your engine every time you run it, and clean it up when through running.

Don't fail to see that the water is flowing properly when the engine is running.

Don't allow water to remain in the water-jacket around the cylinder while the engine is idle on a cold day.

Don't forget to throw off the switch or disconnect the wire when through running.

Don't blame the engine at once if it doesn't run; look for the trouble till you find it—like as not it may be your fault.

Don't look for gasoline leaks with a lighted lamp or match.

Don't fail to examine your engine occasionally.

ENCLOSED ARC LAMPS—I

WITHIN the last six or eight years the methods used for operating arc lamps and the arc lamps themselves have undergone great

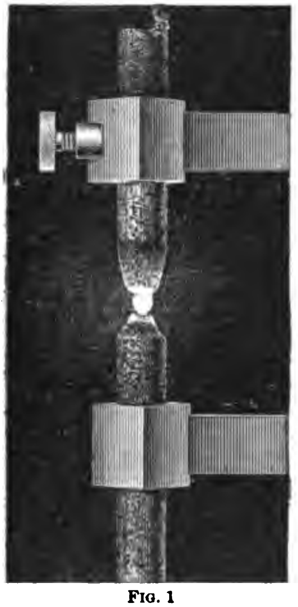

FIG. 1

changes. This has been due largely to the introduction of the enclosed arc lamp. In the older style of lamp the arc is formed between carbon points to which the air has free access. This style of arc, known as the open arc, is shown in Fig. 1, which is here given so that the characteristics of the enclosed arc may be compared with those of the open. The upper carbon is the positive, so that the current flows from the upper to the lower. The carbons become pointed after the arc has burned a few minutes and take on the form shown by the sectional view in Fig. 2. The upper carbon burns about twice as fast as the lower, and a small cup-shaped spot or crater *a* is formed in it. The bottom carbon is much more pointed than the upper and does not attain to such a high temperature. The greater part of the light is emitted from the crater, and is thrown downwards at an angle of about 45 degrees. The temperature of the arc is exceedingly high and difficult to measure accurately, but it is estimated to be about 3,500 degrees Centigrade.

Ordinary open arc lamps require a current of about 9 to 10 amperes, though some of the smaller lamps operate at 6.6 amperes. The voltage required is about 45 to 50 volts across the lamp terminals.

The chief objection to the open arc is that the carbons burn away at a comparatively rapid rate, thus making it necessary to trim the lamps daily. The positive carbon, if of the ordinary $\frac{1}{2}$-inch or $\frac{9}{16}$-inch sizes, will burn about $1\frac{1}{2}$ inches per hour, though, of course, the rate of burning depends somewhat on the hardness of the carbon. Also, the light from the open arc is not suitable for interior illumination, as it has too much of a glare unless it is toned down by means of opal globes or other devices that generally cut off at least 50 or 60 per cent. of the light.

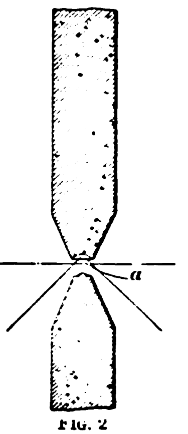

FIG. 2

A great step in advance was made by the introduction of the enclosed arc lamp, which was first brought out by Mr. Louis B. Marks, and which is now widely used both for indoor and outdoor illumination. The chief point of difference between the two lamps is that the newer style has its arc enclosed in a small globe which, while not air-tight, keeps the

air away from the carbons to such an extent that the rate of carbon consumption is greatly decreased. Fig. 3 illustrates the arrangement of the carbons and enclosing globe. The enclosing globe is shown at *G*, and it is usually 5 to 6 inches long and about 3 inches in diameter. This globe is provided with a gas cap *P* through which slides the upper positive carbon *A*. The lower carbon *B* is held firmly in the holder *C*, and the globe is held down tightly against the surface *C* by means of the holding device shown in the figure. In some holders an asbestos washer is placed

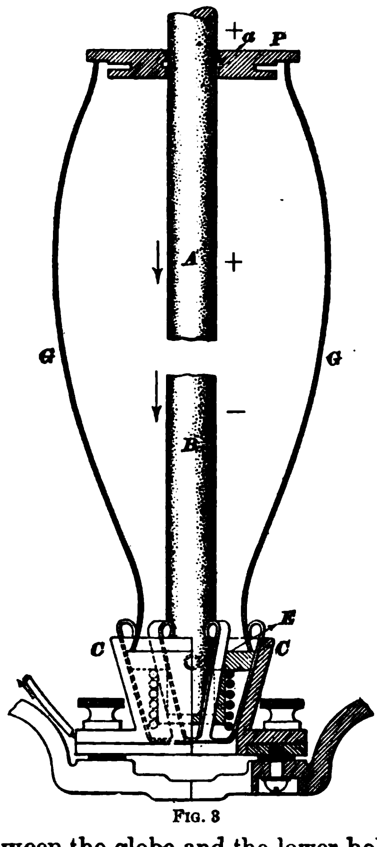

FIG. 3

between the globe and the lower holder in order to distribute the strains and avoid breakage. The cap *P* is often provided with an annular groove *a*. This leaves less surface for the carbon to rub against and affords a space in which eddies are formed by the hot air passing up, thus tending to keep fresh air out of the bulb.

FIG. 4

The result of enclosing the arc as above described is that most of the oxygen present is soon burned out, and the arc burns in a hot atmosphere of carbon monoxide, nitrogen, and a small amount of oxygen. It is necessary to have a small amount of oxygen present in order to combine with the small amount of carbon given off, and thus prevent its being deposited on the enclosing globe.

The general appearance of an enclosed arc is quite different from that of the open arc, as shown in Fig. 4. The ends of the carbons are nearly flat, and the light is of a softer and more pleasing character than that given off by the open arc. The flat ends of the carbons are probably due to the fact that the enclosed arc does not remain in one place, but shifts about over the ends of the carbons. There is no well-defined crater as in the open arc, and the arc is very much larger. It is necessary to use a long arc with enclosed lamps for two reasons. With a short arc there is a tendency for the carbons to deposit soot on the inner globe, and, on account of the flat ends of the carbons, a large part of the light from the upper carbon would be obscured if the carbons were not well separated. The length of the arc depends on the voltage at which the lamp is operated. A common length is about $\frac{3}{8}$ inch with a pressure of 70

to 80 volts across the arc. Enclosed arcs are usually operated with a smaller current than the open arcs, 6.6 amperes being a common current for series lamps. Some of the smaller sizes and high-voltage lamps operate on currents as low as 2 to 3 amperes. Enclosed arc lamps are made in all styles and sizes, and for both direct and alternating current. Lamps intended for operation on constant-potential circuits are usually made for 110 or 220 volts, and require either a resistance or a choke coil in series with the arc to steady the operation of the lamp. Fig. 5 shows a common type of constant-potential enclosed lamp for direct-current circuits. *R* is the resistance, *M* the regulating magnet for controlling the feeding down of the upper carbon, *p* is the movable iron core of the magnet, and *d* is a dash-pot to steady the movements of the core. Fig. 6 shows the connections of the lamp. The current enters at the positive binding post, flows through the resistance *R*, passes around the coils *MM* to the upper carbon holder by means of a flexible cable, thence to the lower carbon, switch *W*, and negative binding post *N*. The upper carbon slides up and down freely in the tube shown in the figure. When current flows through the lamp, the magnets draw up the core *p*, thus causing the clutch *r* to grip the carbon and raise it. This starts the arc, and as the lamp burns, the arc gradually lengthens, thus increasing the resistance of the lamp as a whole. The pressure across

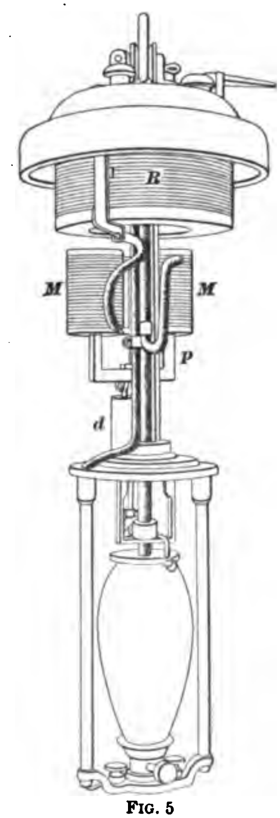

FIG. 5

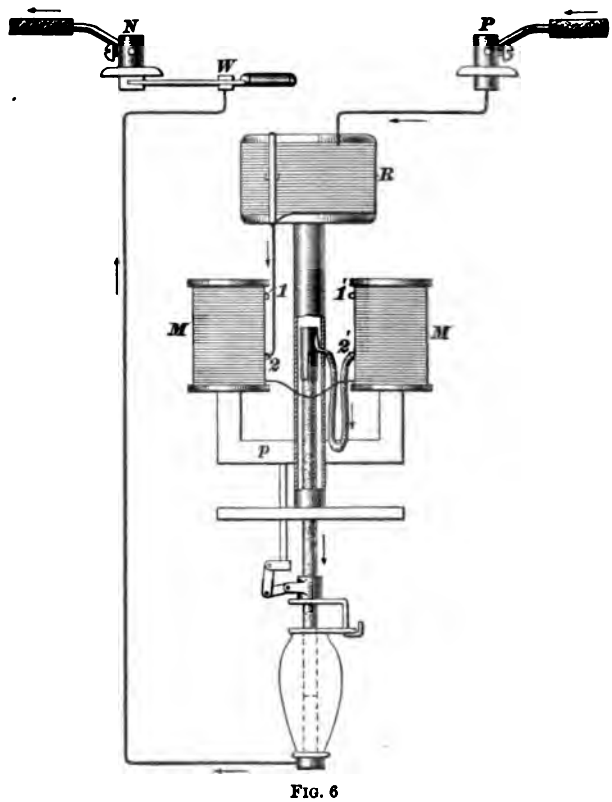

FIG. 6

the lamp terminals is constant; hence, the current in the coils *M M* becomes smaller and *p* lowers until the clutch rests on the tripping table *s*, when any further downward movement of *p* releases the clutch and allows the lamp to feed. It must be remembered that this style of lamp is intended for operation on a *constant-potential* circuit; hence, the current in the regulating coil will vary with the length of the arc, and the regulation of the lamp can be effected with a simple series coil or pair of coils. The resistance *R* can be adjusted so that the lamp will operate satisfactorily on any pressure from 100 to 120 volts. The series coils are provided with two connections 1, 1′ and 2, 2′, so that the lamp may be made to operate at 4½ to 5 amperes or 3½ to 4 amperes. When the larger current is used, the connections are as shown in the figure, because few turns are then needed to operate the plunger. This lamp used solid carbons ½ inch in diameter. The voltage at the arc is about 80, leaving 20 to 40 volts to be taken up in the resistance.

A word or two regarding the resistance used in constant-potential lamps may not be out of place here. Of course, this resistance takes up the difference in voltage between that of the arc and that of the line, but it also fills a more important function, i.e., steadying the action of the lamp. One peculiar property that the electric arc has as a conductor, and in which it differs from metallic conductors, is that its resistance decreases with an increase of current. The reason for this is that an increase in current causes an increase in the cross-section of the arc, and, as the length remains nearly fixed, the result is a decrease in resistance. On the other hand, a decrease in current results in an increase of resistance. Suppose the arc were connected directly across constant-potential mains supplying a voltage equal to the normal voltage of the arc and without any resistance in series with the arc. If the current for any reason were increased slightly, the result would be a decrease in resistance, and this would tend to

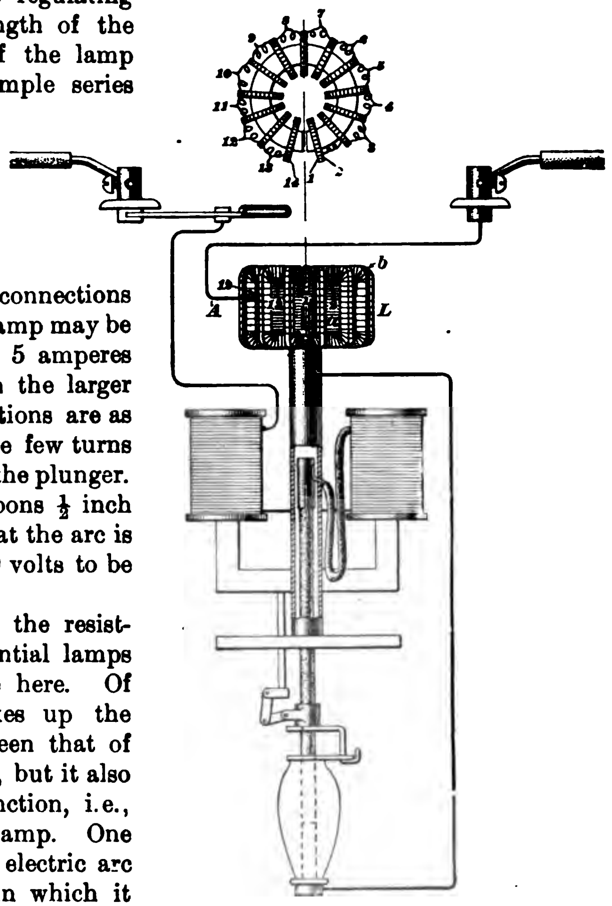

FIG. 7

make the current increase still further, thus causing flaming of the arc. On the other hand, a decrease in current would cause an increase in resistance which would still further decrease the current, and the arc would not burn up to full brightness or might even go

out. Now consider the case when the line voltage is somewhat greater than that of the arc and a resistance is inserted in series. The lamp at once becomes stable in its action for the following reason: Suppose the current decreases a little; the drop through the resistance will decrease and, since the line voltage is constant, the pressure across the arc will be increased, thus compensating for the increased arc resistance. Also, if the current increases, the drop through the resistance at once increases and the voltage across the arc is lowered. In alternating current constant-potential lamps a *reactance* or *choke coil* takes the place of the resistance. This coil is wound on an iron core, and when an alternating current passes through the coil the changing magnetism generates a counter E. M. F. which varies with the amount of the current, and thus gives stability of operation.

The choke coil wastes less energy than the resistance, but, of course, it cannot be used with a direct-current lamp, as the direct current is not capable of setting up the alternating magnetism necessary for the generation of the counter E. M. F.

Fig. 7 shows an alternating current constant-potential lamp. Its construction is practically the same as the lamp shown in Fig. 5, except that the resistance is replaced by the choke coil *L*. The wire *A* may be connected to any of the terminals 11, 12, 13, etc., thus allowing the lamp to be adjusted for a considerable range of voltage and frequency. Alternating-current arc lamps operate best on frequencies of 60 cycles per second or higher. Lower frequencies do not give as satisfactory results. All magnet cores in alternating-current lamps must be well laminated.

For series arc circuits, the current is maintained at a constant value, and the regulating mechanism of series lamps has to be considerably different from that of the constant-potential lamps which are always operated in multiple. In the next article, series lamps will be considered.

SOME RULES FOR CASTING ALUMINUM

IN a recent issue of the Foundry some rules for casting aluminum are given by Mr. H. Tuttle. The metal should be poured as cold as possible, thin castings being harder than those of heavier sections, but on general principles the rule holds good in all cases. A convenient way of ascertaining the temperature of the metal is to stir it with a pig of aluminum, if its color is red, until it is white, the melting of the pig serving as a guide to this point. The end of the cooled pig is then dipped three-quarters of an inch or so into the metal, the aluminum chills around the pig, and when the latter is withdrawn from the melted metal it remains like a little cup on the surface of the handle. The time required for this chloride metal to melt gives a good idea of the metal in the crucible. Dry sand is to be used and sponging the mold is to be avoided. The metal is to be poured very rapidly, as it is not as liable to wash away portions of the mold as other metals on account of its lightness. It is not necessary to ram the molds nearly as hard as for iron. Soft ramming will prevent the breakage of castings, as aluminum just after it solidifies is very weak and crumbling and will scarcely bear its own weight.

SOME POINTS ON THE RUNNING AND MANAGEMENT OF BELTS—II

WHEN a machine requiring, say from 10 to 20 horsepower, is to be belted up, and the pulleys are rather small with no opportunity of using larger ones in order to obtain a higher speed, or of using pulleys having a greater width of face, it is evident the questions of adhesion and tension must be seriously considered. It has been seen that in order to transmit a given number of horsepower with small pulleys running at a low speed, a high degree of adhesion is absolutely necessary however it may be obtained. It has also been pointed out that the necessary adhesion can oftentimes be obtained by keeping the belts in first-class condition, which is in the long run by far the cheaper method. But if the load is to be increased beyond the point where a well-kept belt when running rather slack will transmit the desired power without slipping, then it will have to be tightened and the tension should be just enough to enable it to carry the load without slipping.

There are times and places in almost every establishment where certain changes cannot well be made, and these circumstances present certain other things that cannot possibly be done, but being able to keep the belts in first-class condition is generally one of the things that can and should be done first of all. If a new belt is to be procured and the conditions are such that it must be run at a comparatively low speed and at the same time transmit considerable power, that is, more power than would ordinarily be thought best under more favorable conditions, the question of tension becomes more important, because if the belt is in good condition and other things remain the same, the power it is capable of transmitting will vary with and depend entirely upon the tension or stress put upon it. It is evident when the stress is to be largely increased it will be necessary to have a belt of greater thickness or one of greater width in order to secure the proper area of cross-section. The average working tension on an oak-tanned leather belt with laced or sewed joints should not exceed 225 pounds per square inch of section; semirawhide 250 pounds, and the best rawhide belts from 275 to 285 pounds.

To illustrate the method of determining whether a belt is suitable for certain work, suppose a given machine or a section of a factory requires 50 horsepower to be transmitted by means of 40-inch pulleys making 160 revolutions per minute. The belt is, say, of rawhide, and 8 inches wide and $\frac{3}{8}$-inch thick. The required tension on the belt is equal to $\frac{\text{foot-pounds}}{\text{velocity}} = \frac{33{,}000 \times \text{H.P.}}{D\,R\,.2618}$, in which D represents the diameter of the pulley and R the number of revolutions per minute. Substituting the values, we have, $\frac{33{,}000 \times 50}{40 \times 160 \times .2618} = 984.7$ pounds. It requires $\frac{1}{.375} = 2.66$ inches in width of this belt to equal 1 square inch of section, so that in an 8-inch belt there are 3 square inches, and the tension or stress per square inch corresponding to the power to be transmitted is $\frac{984.7}{3} = 328.2$ pounds, which is about $1\frac{1}{8}$ times the tension it ought to have. Even though the belt were kept in first-class condition, this alone would probably not be sufficient to prevent slipping. Under these circumstances the belt

would not be well adapted to the work. In order to obtain a successful drive, one of three things would necessarily be done, viz., larger pulleys

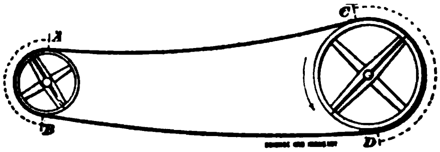

FIG. 1

would be substituted, or the speed increased, or a thicker or wider belt put on. In this case, tightening the belt would no doubt enable it to transmit more power, but the net gain by so doing would be found to be about zero, on account of the ultimate loss due to injuring the belt by overloading it. Tightening the belt beyond that necessary to transmit the required number of horsepower, assuming the belt to be properly proportioned, in the first place is productive of other evils than injury to the belt. Hot bearings, broken pulleys, and a more rapid wearing out of the entire system of transmission, to say nothing of the additional power required to overcome the increased friction, are some of the results of over-burdening belts.

The arc of contact, other things being equal, has an important influence upon the behavior of a belt and upon the amount of power it can transmit. For instance, a belt will only transmit 65 per cent. as much power with an arc of contact of 90 degrees as it will when the arc of contact is 180 degrees.

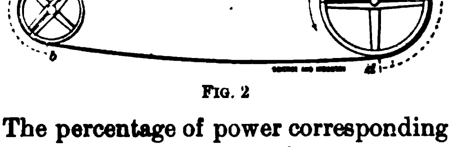

FIG. 2

The percentage of power corresponding to the various degrees of contact is as follows: 100 degrees, 70 per cent.; 110 degrees, 75 per cent.; 120 degrees, 79 per cent.; 130 degrees, 83 per cent.; 140 degrees, 87 per cent.; 150 degrees, 91 per cent.; 160 degrees, 94 per cent.; 170 degrees, 97 per cent.; 200 degrees, 5 per cent. more than at 180 degrees, the latter corresponding to 100 per cent. It is important when arranging a belt drive to endeavor to so proportion the pulleys and the distance between the shafts that the arc of contact on both pulleys may be kept as large as possible. The larger this factor, the less tension is required to transmit a given number of horsepower, or if the power remains the same, then the speed of the belt may be reduced without necessarily interfering with its efficiency. When one

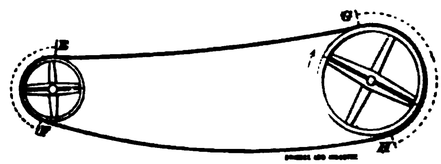

FIG. 3

pulley is considerably smaller than the other, a rather high tension is required, and it frequently becomes necessary to increase the width of belts under these conditions, not because the width in itself adds to the adhesion, but in order to secure a larger cross-sectional area to better resist the higher tension, the latter being unavoidable, owing to the smaller arc of contact on the smaller pulley. When finding the width of a belt where one pulley is somewhat smaller than the other, the constants used in the formula for obtaining the width of belts should be increased. The amount to be added to these constants may be found by means of the formula $540 - \left(\frac{a\,1{,}080}{c}\right) =$ amount to be added, in which $a =$ length of arc of contact on smaller pulley and

$c =$ the circumference of the smaller pulley.

Better results are obtained when the direction of the belt is such that the slack side will come on top, that is, so that the slack side of the belt will run off the top of the driving pulley and onto the top of the driven pulley. This arrangement preserves, and, in some cases, tends to increase the arc of contact, as shown in Fig. 1, and also tends to prevent slipping to a considerable extent, without increasing the initial tension. In this case the tension will be just sufficient to carry the load without noticeable slipping, which is the result most to be desired.

It will be seen, by referring to Fig. 2, that an increase of load within certain limits only tends to increase the arc of contact and that if the belt is kept in

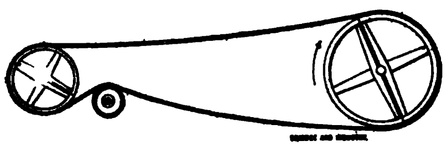

FIG. 4

good condition, so as to get the greatest possible adhesion, the maximum horsepower can be then transmitted with the least friction, and, consequently, with the least fuel. The arcs of contact in Figs. 1 and 2 are measured between the points $A\ B$ and $C\,D$ and between $a\,b$ and $c\,d$, respectively. If the direction of the belt were reversed, the conditions illustrated in Fig. 3 would obtain and the arcs of contact would then be reduced, as shown by the distances $E\,F$ and $G\,H$. In order to transmit the same or more power, a tightener would be placed near the smaller pulley, as shown in Fig. 4, and should the belt be neglected and become dry and hard, it will be necessary to use a tightener near both pulleys, as in Fig. 5. While this arrangement does not tend to injure the belt particularly, it does add four bearings to provide oil for and to be regularly cared for, and it is plainly

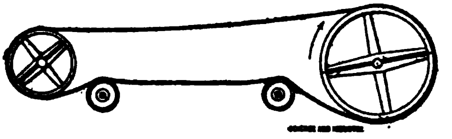

FIG. 5

seen that many such arrangements will make a considerable difference in the power and fuel required.

The arrangement of belt drive shown in Fig. 5 is not a common one in well-designed systems of transmission, because it can be readily understood that where certain changes elsewhere in the mill or factory can be made so as to avoid the use of idlers and tighteners it is generally done, and it is usually cheaper in the long run, on account of the large frictional losses it is possible to avoid by so doing. But it is only by experience and the study of belt problems that the belt doctor acquires his education along this line and the ability to foresee the necessity of these wasteful arrangements, and to be able to avoid them whenever possible. A belt drive is, indeed, a simple contrivance for transmitting power; nevertheless to properly proportion the pulleys and belts, to determine the proper speeds, and the most suitable

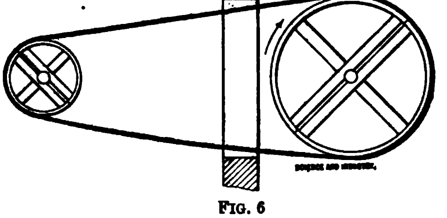

FIG. 6

direction to run the belts in a large establishment in order to secure maximum economy, all things considered, will be found to be much less simple

and to require hours of very careful study and close figuring. It is on this account, principally, that several undesirable power-absorbing arrangements

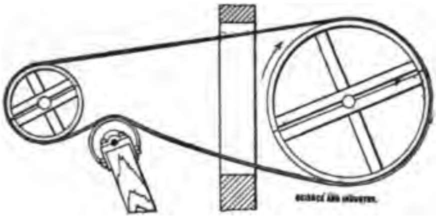

FIG. 7

are illustrated, and their adoption should be studiously avoided by the belt doctor when laying out a new drive.

It sometimes becomes necessary to place two shafts rather close together, as illustrated in Fig. 6. These may represent two line shafts, or a line and a jack-shaft. In either case, a short belt, as shown in the drawing, will not work satisfactorily for any great length of time without a great deal of unnecessary time and labor being put upon it. The drive might be arranged, as in Fig. 7, which will render the belt capable of carrying a heavier load, but the tightener will have to be crowded hard against the belt, which will add largely to the unnecessary friction and will be very apt to give a great deal of trouble. Where an undesirable arrangement of shafts of this kind cannot be avoided, it is generally more economical to put up a countershaft, or jack-shaft, as the case may be, at some dis-

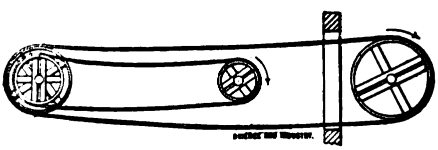

FIG. 8

tance from the driving shaft and then belt back to the driven shaft, as shown in Fig. 8. Narrower belts and pulleys can then be employed, better belt speed can generally be obtained, and while the arcs of contact on the larger pulleys are slightly less, the tension is proportionately greater, although the actual initial tension required is reduced to the minimum for a given number of horsepower transmitted. The belts in the latter case will be considerably longer, and the sag tends to produce the required arc of contact on the smaller pulley.

Vertical belts are, as a rule, more difficult to keep in proper running order than horizontal ones. In the horizontal drive, as the load increases and the slack becomes greater, the arc of contact is increased, provided the belt is run in the proper direction, but with the vertical drive, as the belt becomes slack the tendency to slip is increased proportionally. The vertical belt tends to drop away from the lower pulley, as shown in Fig. 9, and, unless it is kept quite tight, slipping will occur even under comparatively light loads. It is not a good plan to keep a belt under high tension any longer than is necessary, that is, when the belt is idle the tension should be removed or greatly reduced. In the horizontal belt, when properly run, this adjustment is made automatically, the belt being subjected to high tension only when transmitting power. The same should hold true with vertical belts, and in order to accomplish it an adjustable tightener that is easily operated should be placed near the driven pulley, as in Fig. 10. By having the proper position of the tightener marked on the frame or floor, it may be quickly set up so as to produce just the right tension to carry the load.

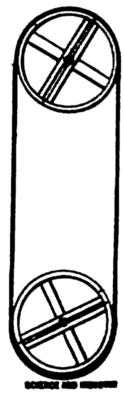

FIG. 9

Some persons in charge of belts require all belts to be thrown off one, and sometimes both, pulleys when not in use, as, for instance, at night. This refers to belts of such size as will readily permit throwing off and on. This, however, is not particularly beneficial except where belts run in damp places or become greasy from the machine upon which they are used. In the latter case the removal of the belts oftentimes serves to avoid the use of tighteners and of having to relace the belts at frequent intervals.

When arranging a belt drive, particularly in a factory where there are perhaps a dozen or more belts running from one shaft, it is a good plan to

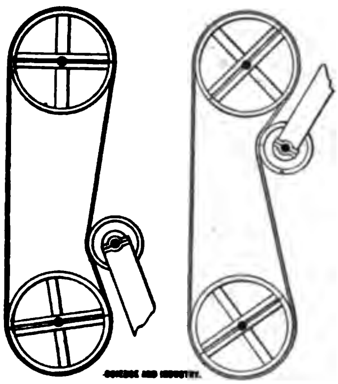

FIG. 10

make a careful study of the arrangement of the machinery, so as to be able to equalize the stress or pull on the shafts as much as possible. For instance, when planning the location of the machinery endeavor to make the arrangement such that the main line of shafting will pass through the center of the factory, so that half the belts will run off on one side and half on the other. This will equalize the pull on the line shaft and tend to reduce the friction at the bearings. Belts pulling in opposite directions, as in Fig. 11, should be placed as closely together as possible, while those pulling in the same direction, as shown in Fig. 12, should be separated so as to distribute

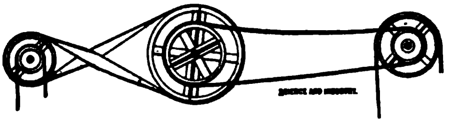

FIG. 11

the stress among as many bearings as practicable. This can be accomplished, oftentimes, by changing the relative positions of the pulleys on the countershaft, and by this means avoiding much of the friction at the bearings, from which no returns can be realized.

Machinery should be so placed that the direction of the belts will be from the top of the driving pulley to the top of the driven pulley. The sag of the belt will thus increase the arc of contact, as shown in Fig. 2.

When the belts have lap joints, they should be run with, and not against, the laps. The direction in which a belt is to run will make some difference in the design of the joints, except when laced, for the hair side of the belt should preferably be placed next to the pulley.

Pulleys should always be a little wider than the belt, in order to avoid

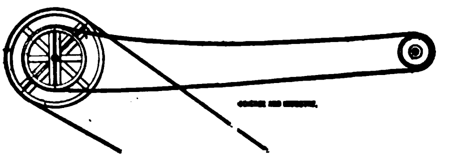

FIG. 12

the tendency to run over the edge of the pulley, which causes unequal stresses and, consequently, unequal stretching.

BOILER TYPES—"THORNYCROFT"

WILLIAM BURLINGHAM

THE majority of the torpedo boats now building for the United States Navy are equipped with the "Speedy Type" of Thornycroft boiler. It is the first large installation of small-tube boilers in the country, and it will be interesting to watch their development from torpedo boats to general marine or land work. Of course they may die a natural death, or yet again they may be developed as a competitor of the ordinary land boiler or the large-tube water-tubular boiler.

The ordinary stationary boiler, as commonly installed, is perfectly capable of generating the high-pressure steam used by our engines today, but with the advent of the steam turbine at pressures from 200 to 500 pounds and the systems of forced draft, either the large or small water-tubular boiler is bound to make its entrance upon the scene of action. With the advancing prices of real estate in the center of our great cities and the necessity, with the present methods of transmitting electrical power, of having the plants in the centers of distribution, they must, of necessity, be located in the congested parts of the city. Therefore, the pressure, capacity, and space required will be the factors in determining the type of boiler to be installed.

This type of boiler is evidently unnecessary for our present type of engine, as to get the highest per cent. of efficiency from a power plant, the boilers and engines must be suited to each other, and the high steam pressures and temperatures of the water-tube boiler would be too much for the ordinary piston-rod packings and engine materials.

The two principal reasons for the use of the water-tube boiler in marine service are, first, the great saving in weight, and second, the increased economy through the use of high-pressure steam. The first does not obtain for stationary work, but we can put in place of it the saving in space. As to the question of economy, we can use the experiments of the British admiralty, embodying as they do over 500 trials of 95 ships. They were all of 12 hours duration and showed that there was actually realized about 90 per cent. of the theoretical gain due to increased pressures. Briefly, 8 per cent. was gained by the use of pressures of 150 pounds, and a gain of 12½ per cent. is expected from 250 pounds. To obtain these results the engine must be designed to suit these pressures, to get the largest number of expansions possible, and to be as light as is consistent with strength.

The special advantages which water-tube boilers are supposed to hold over the ordinary boilers are:

1. Better means of obtaining higher working pressures, because of the excessive thickness of plates for shells and heating surface in the ordinary type of boiler and the consequent difficulty of bending, flanging, and riveting same.
2. Economy of maintenance.
3. Increase of power given out by a boiler occupying a given space and of a given weight.
4. The freedom from serious accident, as the only practical explosion possible would be due to the bursting or splitting of a tube, in which case, with the automatic doors now used, the steam, etc., would go up the stack.

A comparison of the weights of a locomotive and Thornycroft type of boiler in a torpedo boat is given in Table I.

There was the same length of ship

in each case—each with two firerooms; but in the case of the water-tube boilers, there were four boilers in each fireroom instead of two locomotive.

The great increase of heating surface of water tube over locomotive boilers shown in table, is to give a greater economy of fuel, though with the same heating surface as the locomotive type the water-tube boiler is equally and probably better able to stand the effects of forcing.

The successful working of the higher steam pressures, in connection with a large number of expansions, affords the means of securing, without inconvenience, a considerable economy of fuel, which economy increases with the pressure.

What is the best means of generating this high-pressure steam? We must abolish the flat-stayed surfaces and thick shell and the large circular furnaces, subject to intense heat and external pressure. In other words, interchange the water and gases; thus making the boiler comparatively small with small water chambers, and the tubes subject to an internal pressure only.

The outer shell now becomes merely an envelope and is used for conducting the gases to the stack.

In 1877, the first Boiler Committee of the British Admiralty, in their Third Report, said as follows:

"The Committee have made further inquiries into this system of constructing boilers, both for marine and land purposes, and the evidence has been of a very satisfactory nature. They believe that such a system of construction, combined with the exclusive use of fresh water and tight condensers, will lead to good results, as regards endurance, safety from explosion, and probable economy."

In 1885 the possible advantage of the Thornycroft type over the locomotive led to its trial in the British Navy, and Torpedo Boat No. 100 was selected and had one of these boilers installed. She was tried in 1886, and for many years was almost continually in service, being retubed once; boiler reported highly efficient. The first large installation, however, was in the Torpedo Boat "Speedy," in 1891, fitted with Thornycroft boilers of 4,500 I. H. P. with the result, that a substantial increase of speed and power was obtained as compared with other ships of her class fitted with the locomotive type.

TABLE I

	Locomotive Boiler	Thornycroft Boiler
Total I. H. P.	3,500	4,500
Number of boilers per ship	4	8
Area of grate per boiler, square foot	45½	25½
Total area of grate per ship, square foot	182	204
Heating surface per boiler of firebox, square foot	272¾	646
Total heating surface per boiler, square foot	1,597	1,840
Total heating surface per ship, square foot	6,388	14,720
Total weight of boiler and mountings dry, tons	82	71.52
Total weight of water in boilers, tons	30	12.78
Total weight of boilers and water per ship, tons	112	84.30
Tons of 2,240 pounds.		

Water-tube boilers may be divided, generally speaking, into two classes: (From H. J. Oram's lectures).

(*a*) "Those with tubes of large diameter, thoroughly accessible, both inside and outside for examination and cleaning, and with their internal steam and water passages so large as to render any obstruction due to dirt or grease

practically impossible; such boilers are suitable for the largest war vessels or cruisers, in which the maintenance of high power for long periods may be desirable."

This type of boiler is the one most generally used in stationary work, and is exemplified in the Babcock & Wilcox, Niclausse and Belleville. In the present design of this general type, there is difficulty in working them under heavy forced draft.

(*b*) "Those with tubes of small diameter, very light for the power developed and capable of being used under high forced draft without leakage of tubes or other injury; to attain these advantages, facilities for cleaning and examination have to a certain extent to be sacrificed; such boilers are suitable for vessels in which machinery of the torpedo-boat type is used."

There are more examples of type *b* in use than of type *a*, and they include such boilers as the Thornycroft, Yarrow, Mosher, Ward, etc.

In No. 100 Torpedo Boat with the Thornycroft boiler, a speed of 16.8 knots was obtained with a fireroom pressure of 2.08 inches of water. The weights were as follows:

	Tons.
Boiler, mountings, furnace fittings, uptakes to bottom stack, brickwork casing and lagging . . .	2.02
Water to working level	.65
Horsepower developed	189

Or 70.8 horsepower per ton boiler weights.

The tubes lasted about 4 years, although at the present writing, with the improved solid drawn steel tubes, we can safely count on a longer period of service.

The general particulars of the Thornycroft boilers as fitted on the U. S. Torpedo Boats in 1899 and 1900 are as follows:

TABLE II

Steam pressure designed	250 lb.
Number of boilers	3
Length of steam drum, feet	10
Width over casing	10′ 8″
Height	10′ 4″
Steam drum, diameter	30″
Water drums, diameter	16″
Length of grate	6′ 9″
Diameter of tubes	1⅛″ and 1¼″
Number of 1⅛″ tubes	776
Number of 1¼″ tubes	140
Heating surface tubes, one boiler	2,516 sq. ft.
Grate surface, one boiler	45.6 sq. ft.
Ratio H. S. to G. S.	1-55.2
Smoke pipes (3), diameter (oval)	39″ × 24⅛″
Area each pipe	5.74 sq. ft.
Safety valves (2), diameter	3¼″
Main stop valve, diameter	5¼″
Heating surface, total 3 boilers	7,548 sq. ft.
Grate surface, total 3 boilers	156.8 sq. ft.

The detail weights of the above boiler are shown in Table III.

The I. H. P. of the boat at 26 knots was 3,250—, equivalent to 27.75 pounds of boiler, stacks, mounts, etc. per I. H. P., and 23.75 I. H. P. per square foot of grate surface.

The boiler consists essentially of a steam drum 30 inches in diameter and ⅜ inch thick, situated at the apex of a triangle, the two lower corners of which are water drums 16 inches in diameter, ⅝ inch thick. The top of the grate is situated about 3½ inches below the center of these water drums. A series of steam-generating tubes are fitted between the upper cylinder and each of the lower water cylinders. These tubes are practically the only heating surface of the boilers. The inner rows on each side are close together for nearly their entire length, with the exception of the spaces at the top and bottom ends, where they are opened to admit of gases entering into the spaces between the tubes. The tubes, being close together, form the roof of the furnace or combustion chamber.

The outer rows on each side are also made into a wall, and the gases cannot escape except through the openings left, for this purpose, at the top. The gases generated in the furnace enter through

the spaces at bottom of the inner wall of tubes into spaces among the tubes. They distribute themselves throughout the entire space enclosed between the inner and outer walls of the nest of tubes and at last enter into the uptake and smoke pipes through the openings at the top. As all of these tubes are so curved as to enter the steam drum above the water level, which is about the center of the drum, there is no chance for the water to circulate back to the water drums; consequently there are provided two downtake water pipes, each 7 inches in diameter by ¼ inch thick. These are located on the front of the boiler, outside the boiler casing. The general working of the boiler is as follows:

The flames and hot gas, entering the spaces between the tubes and emerging at the top on their way to the stack, cause a rapid circulation of the water in an upward direction through the tubes, some portion of it being turned into steam; as it leaves the upper end of the tubes it strikes against a system of baffle plates, which in a measure acts as a separator, guiding the water down to the water level of the drum and allowing the dry steam to pass through. On the outside of these tubes is fitted a casing of steel-plate and fire-proof, non-ducting material to prevent the waste of heat. The casing consists of, first a sheet of ¼-inch asbestos board, then No. 16 U. S. S. G. galvanized steel plate, then 1 inch of magnesia or asbestos, and finally another galvanized steel plate No. 16 U. S. S. G. This covering is put on in sections that are easily removable, so that ingress to the tubes is possible when the boiler is in place. The front, back, and sides of the furnace space are lined with firebrick. The bricks are grooved and tongued, and practically every other brick is secured by square-headed bolts to the steel plate

TABLE III

Weight Thornycroft Boiler.

Heating surface 2,516 square feet
Grate surface 45.6 square feet
Steam pressure 250 pound gauge
Weight per square foot, heating surface: dry 10.2 pounds, wet 11.9 pounds.

Boiler drums, steel.	*Pounds.*
1-30″ drum 10′ long	2,350
2-16″ " 9′ 3″ "	2,052
2-7″ downtakes	348
2-12″ × 14″ manholes	66
2-8″ diam. "	50
2-13″ x 10′ "	86
Tubes, Steel.	
140-1¼″ No. 11 B. W. G.	1,788
776-1⅛″ No. 11 "	10,144
Baffles, braces, etc.	50
Zincs and baskets	201
Clips, rivets, etc.	
steel	673
Firebrick	917
clay	363
steel	10
Grate bars and bearers.	
cast iron	1,158
steel bars	468
rivet rods	38
gas pipe	30
Boiler casing.	
steel plates	2,089
" shapes	567
rivets, bolts, etc.	162
magnesia	418
asbestos	137
Fire doors	231
Furnace light hole and soot door	69
Feed regulating gear	81
Safety valve	150
Three gauge-cocks	10
Stop-valve connection	41.33
Main and auxiliary stop- and check-valves	60.99
Mica water gauge	35.00
Glass water "	21.66
Water columns	52.40
Boiler stop-valve	185.00
By-pass cock	4.00
Miscellaneous mountings	90.67
Water to working level	4,360.00
Totals.	
Weight, dry, pounds	2,5207.05
Weight, dry, tons	11.25
Weight, wet, pounds	2,9567.05
Weight, wet, tons	13.20
Metals.	*Pounds.*
Steel in drums	4,402.00
tubes	11,932.00
plates	2,310.00
shapes	613.00
miscellaneous	2,039.00
Wrought iron	63.33
Cast iron	1,168.00
Composition	582.40
Brass	45.66
Bronze	24.67
Zinc	1,90.00
Manganese	418.00
Firebrick	917.00
Clay	363.00
Asbestos	137.00
Rubber, Glass, Packing, etc	2.00
Total	25,207.05

forming the casing. With forced draft, this or a similar method is necessary to prevent the wall collapsing, and is the result of expensive experience. The lower row of bricks near the grate are especially large, about 12 or 13 in. square. They are set in fireclay.

These boilers cannot be worked at a high rate of power with salt water feed, but that would not make much difference for stationary work. At first there was trouble because of the gate bars melting and dropping, but a very little experience on the part of the firemen in keeping the grates well and evenly covered soon stopped this. The bars are made of steel, and are put together in groups of six. They are very thin and deep, with wide air spaces, and are practically the only bar in use with successful boilers. Cast-iron bars were used of about the same section, in groups of two, but with equally skilled firing they did not last as long. To instance the heat that these bars must have undergone, I will say that some of these boilers were run under nearly 8-inch water pressure and burned nearly 100 pounds coal per square foot of grate surface per hour. The end stays are fitted to prevent the sagging of boilers when the tubes are undergoing the immense heat of the fires. These stays are a very desirable feature, although many boilers have been built without them. The fire doors are made of thin steel plate $\frac{1}{8}$ inch thick, backed by four baffle plates spaced $\frac{3}{8}$ inch apart. This type of door is very good, losing its heat rapidly, the baffle plates, only, being required to be renewed. The hinges are set so that the door will close of itself when not held back.

The boiler mountings are arranged with the mica water gauge on one side and the glass water gauge on the other. In the middle, between the two, is the feed-regulator hand wheel. The feed check-valves are on the left, just below the center of the boiler, and the surface blow is on the right at the center.

Both the main and auxiliary feeds discharge at the bottom of the drum, the main feed after passing through a Thornycroft feed regulator. The operation of this feed regulator is as follows: The steel floating counter, balanced by the cast-iron weight, is set to hold a double poppet valve in position desirable for the feed admittance. If water begins to get low in the boiler, or vice versa, the float drops or rises, opening or closing the feed admittance through the double poppet. This water level is adjustable by means of the hand wheel outside the boiler.

Zinc plates are provided for preventing galvanic action between the different parts of the boiler. The government requirements for these plates are that they must be of rolled zinc of standard size, 6 ft. $\times$ 12 in. $\times$ $\frac{1}{2}$ in. or submultiple thereof. There must be $\frac{3}{4}$ of a square foot of exposed zinc surface, exclusive of edges, for each 100 square feet of heating surface in the boiler. Each strap for holding zinc plates must be filed bright at contact and joints made water-tight with cement covering.

The general specifications under which these boilers were built are as follows:

The total grate surface will be at least 137 square feet, and the total heating surface at least 7,544 square feet. Efficient means must be provided for getting at the interior of such parts of the boiler as require attention for examination, cleaning, or repair. They will be built to withstand a working pressure of at least 250 pounds per square inch. All parts of the boiler must be readily accessible for cleaning and painting.

Boiler Tubes.—They will be seamless, cold-drawn steel tubes of the following thicknesses:

1 inch diameter outside, No. 12 B. W. G.

$1\frac{1}{8}$ inch diameter outside, No. 11 B. W. G.

$1\frac{1}{4}$ inch diameter outside, No. 11 B. W. G.

The tests for these tubes are those generally required for government work.

The plates used in the construction of the steam and water drums must show a tensile strength of between 60,000 and 66,000 pounds per square inch, with an elastic limit of at least 32,000 pounds per square inch, and an elongation of at least 25 per cent. in 8 inches.

Downtake pipes will be made of mild steel to stand a severe test.

All rivets will be made of material to correspond with the class of plates with which they are used.

All longitudinal seams will be welded where possible; all circumferential seams will be welded.

All holes will be drilled with the plates in position. When the holes are drilled, the plates will be separated for the purpose of removing all burrs. When possible, hydraulic riveting will be used; seams will be calked on both sides in an approved manner.

In parts where hydraulic riveting cannot be used, the rivet holes will be coned and conical rivets used.

There will be manholes and handholes whenever necessary for examination, repairs, and preservation of the boilers.

The manhole plates will be of cast steel in dished form of approved pattern. The tensile strength of these castings shall be at least 70,000 pounds per square inch, with an elongation of at least 10 per cent. in 8 inches, or 15 per cent. in 2 inches, in case 8-inch specimens are not procurable, and a reduction in area of at least 20 per cent.

There will be a $\frac{1}{16}$-inch steel templet for each manhole and handhole plate, suitably marked.

The furnace doors will be of approved pattern, and they must be protected from the heat of the fire. If air is admitted to the furnace through the ash-pit doors, they must be of the automatic-closing type.

Automatic self-closing doors will be fitted for admitting air to the furnaces above the grate bars. Slicing doors must be fitted in each furnace door.

The grate bars for all boilers will be of approved pattern. The bars will be of the same length and interchangeable. The bearers will be made of steel.

The boiler casings will be made of steel of approved thickness, lined with magnesia or other approved fireproof, non-conducting material. They will be made in sections and fitted so as to be easily removable, and will have doors where necessary for cleaning. The part forming the uptakes will be bolted to the lower plates of the smoke pipe with slotted holes to allow for expansion. Each boiler will have the following attachments:

One steam stop-valve.

One auxiliary steam stop-valve.

One dry pipe.

One main feed check-valve with internal pipe.

One auxiliary feed check-valve to connect with internal pipe.

One bottom blow valve with internal pipe.

One surface blow valve with internal pipe and scum pan.

One twin safety valve.

One steam gauge.

One glass water gauge, automatic-closing type.

One mica water gauge, automatic-closing type.

Four gauge-cocks.

One drain cock.

One air cock.

One automatic-feed regulator.

Water connections with valves and pipes for extinguishing furnace fires in case of accident.

Hose nozzle to fill boiler with water from deck, etc.

All external fittings will be of composition unless otherwise directed. All fittings will be flanged and through-bolted or attached in other approved manner.

All cocks, valves, and pipes will have spigots or nipples passing through the boiler plates.

All internal pipes will be of brass, No. 14 B. W. G., and must not touch the plates anywhere, except where they connect with the external fittings. The internal feed and blow pipes will be expanded in the holes in the boiler shells to fit the nipples on their valves, and will be supported, where necessary, in an approved manner. The stems of all valves on boilers are to have outside threads.

The dry pipe will be located in the steam drum, as high as possible, of brass or tinned copper, extending nearly the length of the boiler, perforated on its upper side with longitudinal slits, the number and size of each such that their combined area will equal the area of the steam pipe.

Each boiler will have spring twin-safety valves, each valve 3½ inches in diameter.

The bottom and surface blows will be 1 inch in diameter.

The drain cocks will be 1 inch and the air cocks ½ inch in diameter.

These boilers will be tested as follows:

Before they are painted or placed in the vessel, they will be tested under a pressure of 360 pounds to the square inch above atmospheric pressure. This pressure will be obtained by the application of heat to fresh water within the boilers, the water filling the boilers quite full.

After the boilers are placed in the vessel and connections are made, the boilers and pipe connections will be tested by steam to 300 pounds per square inch, and all leaks made tight.

DIMENSIONS, ETC., THORNYCROFT SPEEDY BOILERS

Total I. H. P.	Dimensions Over Casings						Tube Surface. Square Feet	Grate Area. Square Feet	Weight with Water to Working Level. Tons	Air Pressure in Stock Hold	Steam Pressure on Trial
	Length Ft.	Length In.	Height Ft.	Height In.	Width Ft.	Width In.					
39		37		31¼		48	139	3.3	0.7	Chimney blast	145
46.7		54¾		62		55	460	6.0	2.21	0.38	130
58		60¼		96		70½	586	12.0	3.78	Chimney blast	—
189		68		72		57	774	8.5	4.3	2.16	145
194		69		73		56	777	8.5	3.28	3.10	150
250		61		80¼		77½	776	11.4	4.3	2.33	140
300		74		90¾		87	1,066	18.0	6.0	—	—
384		65		79		80	937	13.0	4.53	3.41	250
400		82		81		66	930	16.0	3.0	2.5	150
450		95		98½	8	10½	1,640	32.0	8.0	—	—
588	8	8	9	3	8	0	2,144	25.5	11.22	1.7	194
650	7	5	8	11	9	7	2,175	30.0	9.805	1.6	—
825	8	2	9	0	9	6	2,418	37.75	11.01	4.0	149
850	9	0	8	9	9	9	2,360	39.0	13.75	2.5	250
930	8	2	9	1	9	4	2,398	37.75	11.665	2.37	217
1,242	8	2	9	6	9	0	2,583	36.8	13.565	2.5	205
1,496	9	6¼	10	2½	13	3	3,095	63.0	15.66	2.75	209
1,548	10	6	10	6	13	0	2,964	63.0	16.79	3.15	204
1,867	11	6¾	10	8½	12	11½	4,020	65.3	18.63	3.5	211

After a satisfactory test, the boilers will be painted on the outside with two coats of brown zinc and oil, and when in place the fronts will be painted with one coat of black paint.

The volume of the water drums is 57 per cent. of that of the steam drum, but can be smaller as the water drums are made of such diameter as to allow of entrance of a man to expand tubes, etc.

ELEMENTARY PRINCIPLES OF ELECTROMAGNETS—III

Principles of Magnetic Induction

THE laws governing the production of magnetism or lines of force through a magnetic circuit are similar in some respects to the laws governing the production of a current in an electric circuit. In an electric circuit an electromotive force, which may be produced in various ways, is necessary before there is any tendency for a current to flow. In a magnetic circuit there is a force called *magnetomotive force* that corresponds to an electromotive force in an electric current. *Magnetomotive force* may be defined as that which produces magnetism, or as that *which tends to produce lines of force in a magnetic circuit against the resistance offered by the magnetic circuit.*

A magnetomotive force may be produced by a permanent magnet or by a wire (preferably, however, by several turns of wire) through which a current of electricity is flowing. The strength of a current that flows in an electric circuit is, by Ohm's law, equal to $\frac{E}{R}$, in which E = electromotive force and R = the total resistance of the electric circuit. For the magnetic circuit we have a somewhat similar law, namely:

$$\text{Magnetic flux} = \frac{\text{magnetomotive force}}{\text{reluctance}};$$

in which reluctance represents the *magnetic resistance* and corresponds to resistance in Ohm's law, and the magnetic flux is the quantity of magnetism passing through the magnetic circuit and corresponds to the current in Ohm's law. The magnetic flux is usually expressed as so many lines of force, one line representing unit flux. Thus, one line of force, for which the name "maxwell" has been adopted, represents a unit quantity of magnetism, the same as an ampere represents the unit of current. In this article magnetic flux will be represented by the letter N.

The above law may be expressed by the following formula: $N = \frac{\text{M. M. F.}}{R}$, in which N = the total number of lines of force threading through the magnetic circuit, M. M. F. = the total magnetomotive force in the magnetic circuit, and R = the total reluctance. When $N = 1$ and $R = 1$ the M. M. F. = 1. Some writers have called the unit of magnetomotive force the "gilbert," after Dr. William Gilbert, who discovered the phenomenon of electrostatic attraction and repulsion in 1600. However, the name is not very generally used at present.

Certain substances are good conductors of electricity, others are very poor conductors, and are termed nonconductors or insulators; for instance, pure copper is about 340,000,000,000,000,000,000,000 times as good a conductor of electricity as porcelain. But the best magnetic material, such as soft iron, in its most permeable condition is only about 2,500 times as good a conductor of magnetism as air, whose

over, all known non-magnetic substances have a permeability of one, the same as that of air; hence, there is no known substance that can be called a very good magnetic insulator or non-conductor of magnetism.

The reluctance of a magnetic circuit depends upon three quantities: First, the length of the circuit; second, the cross-sectional area of the circuit; and third, the permeability of the substance forming the magnetic circuit. The reluctance is best expressed by the following formula: $R = \frac{l}{A \times u}$, in which R is the reluctance in C. G. S. units when l is the length of the magnetic circuit in centimeters, A its sectional area in square centimeters, and u the permeability of the magnetic substance. Some writers have called the unit of reluctance the "oersted," after Oersted, who discovered the phenomenon of electromagnetism in 1820. However, this name is not very generally used at present. Since air and all non-magnetic substances have a permeability of 1, it follows that the reluctance of a magnetic circuit through air $= \frac{l}{A}$.

Reluctance of a Compound Circuit.

A magnetic circuit usually consists of two or more substances; for instance, a dynamo field and armature cores are usually of good soft iron, the yokes cast iron or steel, and the gaps between the field and armature cores are air. The reluctance of such a compound circuit must be computed by adding together the reluctances of each portion. If $R_1 = \frac{l_1}{A_1 u_1}$ is the reluctance of both cores of an ordinary 2-pole magnet, $R_2 = \frac{l_2}{A_2 u_2}$ the reluctance of the yokes, $R_3 = \frac{l_3}{A_3 u_3}$ the reluctance of the armature, and $R_4 = \frac{l_4}{A_4 u_4}$ the reluctance of the two air gaps ($u = 1$ in last case); then, for the total reluctance R of the magnetic circuit, we have $R = R_1 + R_2 + R_3 + R_4$. Now we have seen that the magnetic flux $N = \frac{\text{M. M. F.}}{R}$, hence

$$N = \frac{\text{M. M. F.}}{\frac{l_1}{A_1 \times u_1} + \frac{l_2}{A_2 \times u_2} + \frac{l_3}{A_3 \times u_3} + \frac{l_4}{A_4 \times u_4}}.$$

Let us change the last expression into the following form:

$$\frac{N l_1}{A_1 \times u_1} + \frac{N l_2}{A_2 \times u_2} + \frac{N l_3}{A_3 \times u_3} + \frac{N l_4}{A_4 \times u_4}$$

$=$ M. M. F., but $\frac{N}{A u} = H$, hence

$$H_1 l_1 + H_2 l_2 + H_3 l_3 + H_4 l_4 = \text{M. M. F.}$$

This formula means that the total magnetomotive force around the magnetic circuit is equal to the sum of the magnetomotive forces in all the various portions of a compound magnetic circuit. That is, $H_1 l_1$ is the magnetomotive force necessary to produce the given flux N through that portion of the magnetic circuit whose length is l_1.

Since $H_1 l_1$ is the magnetomotive force in that portion of the circuit whose length is l_1, H_1 is often said to be the magnetomotive force per unit length in that particular portion of the circuit. If B_1 is known, H_1 can be taken directly from a curve, then by multiplying this H_1 by the length l_1 we have the magnetomotive force for this one portion of the magnetic circuit. In a similar manner the magnetomotive forces for other portions can be obtained.

The field density H produced inside a solenoid may be calculated by the formula $H = \frac{4 \pi I T}{10 l} = \frac{1.257 I T}{l}$, in

which I is the current in amperes flowing through the coil, T the number of turns in the solenoid, and l the length of the solenoid. If the return path for the lines of force set up inside a solenoid is through air, then the formula is only approximately correct. For a very long solenoid it is sufficiently correct for practical purposes.

The product $I\,T$ is called the ampere-turns since it is the current in amperes multiplied by the number of turns in the coil. Hence, $H = \frac{1.257 \text{ ampere-turns}}{l}$, or ampere-turns $= \frac{H\,l}{1.257}$. This formula can only be used when the dimensions of the magnetic circuit are given in metric units. When given in English units, the value of the constant is changed and the formula becomes ampere-turns $= \frac{H\,l}{3.192} = .313\,H\,l$, in which H is the field density per square inch and l the length in inches.

In practice the magnetic flux is usually given, and it is the ampere-turns necessary to drive the given flux through the magnetic circuit that has to be calculated. Suppose the flux is N. The next thing to do is to decide upon the flux density B to be used. It is customary in wrought-iron cores to allow a magnetic density of about 90,000 lines of force per square inch except for lifting magnets, in which the density runs as high as 100,000 to 110,000. In cast-iron yokes a density of 30,000 to 40,000 lines per square inch is allowed. This would, of course, vary somewhat with the permeability of the iron used. Having decided upon the density, the cross-section A is found by dividing N by B. Having determined B, the next thing is to find from a curve the ampere-turns per inch necessary to produce B.

Now a curve showing the relation between B and the ampere-turns per inch of length, that is, between B and $.313\,H$, is more convenient in designing work than one between B and H. For it is evident that if we have B for any portion of the magnetic circuit, then the ampere-turns for that portion may be calculated by simply taking the value of $.313\,H$ directly from the curve corresponding to the value of B and multiplying it by the length of the same portion of the magnetic circuit.

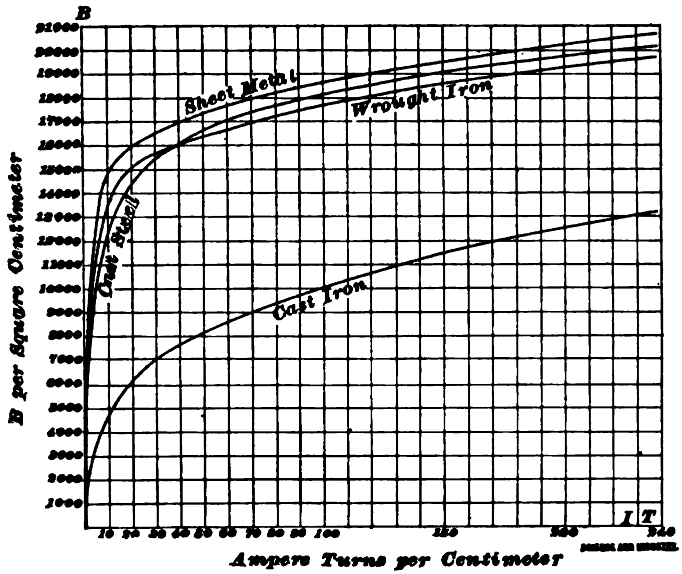

FIG. 1

Curves showing the relation between the magnetic flux per square centi-

meter B, and the ampere-turns per centimeter length of the magnetic material IT for sheet iron, cast steel, wrought iron, and cast iron are given in Fig. 1. A similar set of curves showing the relation between the magnetic flux per square inch and the ampere-turns per inch length of the magnetic material are given in Fig. 2.

Magnetization curves will frequently be found plotted with H, the field density in lines per square centimeter, as the abscissas and B the magnetic density per square centimeter, as ordinates, as in Fig. 3 (a), which was shown on page 320 in the June, 1902, Science and Industry, and it will often be desirable to convert the values taken from such a curve into the more convenient units; that is, B into lines of force per square inch and H into ampere-turns per inch of length. Now $H = \frac{4\pi IT}{10 l}$, in which I = current in amperes, T = number of turns of wire in the coil, and l = the length of the magnetic circuit in centimeters, and $\pi = 3.1416$. Then the ampere-turns per centimeter of length $= \frac{10 H}{4\pi}$ and the ampere-turns per inch of length $= \frac{2.54 \times 10 H}{4\pi} = 2.02 H$. Therefore, the ampere-turns per inch of length are approximately equal to $2H$, in which H is the magnetizing force in C. G. S. units; that is, the lines per square centimeter in air.

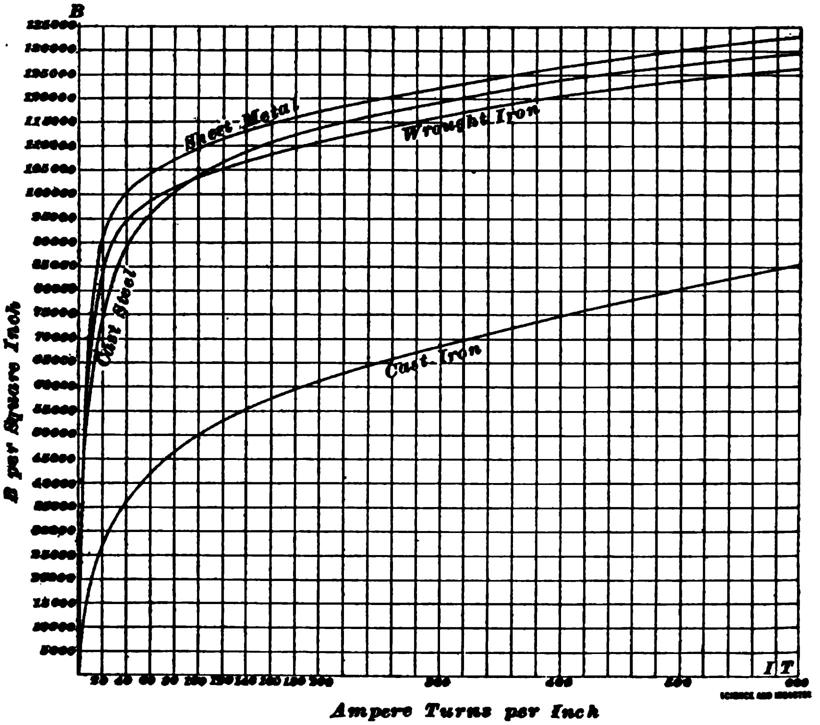

Fig. 2

The number of lines of force per square inch in the iron $= 6.45 B$, in which B is the number of lines of force per square centimeter.

Thus the ampere-turns necessary to produce the given flux N in the cores,

yokes, air gaps, etc. may be obtained as explained above. Adding together the ampere-turns for each portion will give the total number of ampere-turns required in the coil or coils. It then remains to decide upon the current strength to be used, after which the number of turns required can be calculated.

A COMPARISON IN ECONOMY

CHAS. J. MASON

SLIDE-VALVE VS. CORLISS ENGINES—STEAM CONSUMPTION PER INDICATOR DIAGRAM—ALLOWANCE FOR LOSSES

IT IS well known that an automatic cut-off engine is more economical in the consumption of steam than is the plain slide-valve engine with a throttling governor. Actual tests have been made from which averages have been determined, and it is upon these findings that the general reading public is enabled to make comparisons and be governed thereby when questions of importance arise.

To the student of steam engineering, and also to the full-fledged engineer who may not have given much attention to the subject heretofore, it will, perhaps, be of interest to learn something of the methods whereby comparisons between engines are made.

Tests are conducted to determine the efficiency of steam engines, that is. to ascertain how close to theoretical requirements they can be made to run. The consumption of steam per horsepower per hour is sought, and this represents the quantity of fuel consumed on the grates. It is the aim of engine builders to so design their machines that the greatest amount of power may be obtained from a given quantity of fuel. The theoretical evaporative power of fuel is taken as the standard with which to make comparisons. The measure of an engine's economy is therefore the quantity of steam consumed in doing certain amount of work, as compared with the theoretical standard.

In the absence of a regular test, in which certain conditions and events are noted, and from which deductions may be made which are practically exact, the indicator diagram can be taken, from which the steam consumption can be approximately calculated. All the steam which passes through an engine will not be accounted for by the indicator, because of leakage and con-

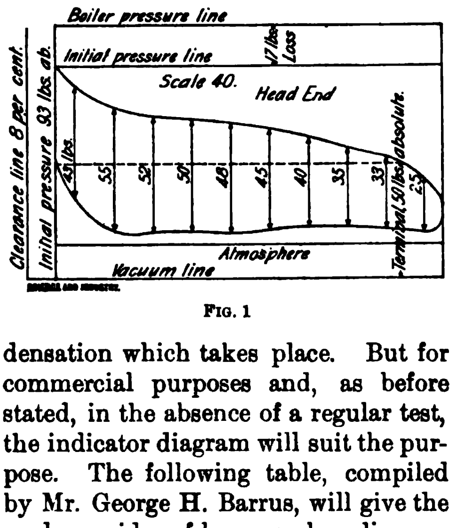

FIG. 1

densation which takes place. But for commercial purposes and, as before stated, in the absence of a regular test, the indicator diagram will suit the purpose. The following table, compiled by Mr. George H. Barrus, will give the reader an idea of how nearly a diagram indicates the actual conditions, and what allowances should be made under ordinary circumstances.

For example, take a diagram from a Corliss engine in which cut-off takes place at ¼ stroke, and the steam consumption per horsepower per hour (at cut-off) is 24 pounds. The feedwater by

measurement is 37 pounds per horsepower per hour. Then, the percentage of steam accounted for by the diagram is $\frac{24}{37} = 65$ per cent., nearly. By the table, this should be 76 per cent. The difference is due to leakage.

Percentage of Stroke Completed at Cut-Off	Percentage of Feedwater Consumption Accounted for by the Indicator Diagram	Percentage of Feedwater Consumption, Due to Cylinder Condensation
5	58	42
10	66	34
15	71	29
20	74	26
30	78	22
40	82	18
50	86	14

TABLE SHOWING PERCENTAGES OF LOSS BY CYLINDER CONDENSATION, TAKEN AT CUT-OFF.

The owner of a steam plant in which there was a slide-valve engine came to realize what a wasteful machine it was. He called in an engineer to consult with, as to the advisability of making a change. The engineer informed him that by installing a Corliss engine in place of the slide-valve engine referred to, a considerable saving would be realized, as far as economy in the use of steam was concerned. In order to emphasize his statement, and yet not go into an extensive and expensive test, he placed an indicator on the engine and took several diagrams from it, the average of which is represented in Fig. 1. This diagram is an exact reproduction, one-half size, of the original, which came into my hands through the courtesy of the engineer who obtained it. The dimensions of the engine are as follows: diameter of cylinder 22″, stroke 28″, revolutions per minute 118, boiler pressure 110 lb. gauge.

From this diagram he obtained the mean effective pressure, from which in turn the horsepower of the engine was found. He made note of clearance space, terminal pressure, percentage of the stroke completed at release, and several other items, which appear on the diagram itself. Let us go over this diagram and see how it reads with regard to the object in view. Now, the object in view is this: It is desired to ascertain the steam consumption of this engine as accounted for by the diagram; and further, to construct a diagram such as a Corliss engine, of the same size and power as the slide-valve engine, would make, so that a comparison can be made and the saving determined.

The diagram as obtained from the engine simply consisted of the irregular-shaped figure with the atmospheric line traced below. The additional lines and numbers are those which were placed to assist in the calculations required. The vacuum line is located at a distance below the atmospheric, as indicated by measurement of the scale, which is 40 pounds to the inch. To those not very familiar with such work it would be well to explain this a little further. The measurement of an indicator diagram depends upon the scale of the spring which is in use at the time the diagram is taken. In our diagram the scale is given as 40. The spring used is of such a size and stiffness that it requires 40 pounds pressure to move the pencil 1 inch in a vertical direction. If the diagram is 2 inches high, then a pressure of 80 pounds has been applied. Now, to locate the vacuum line, we measure down a distance equal to 14.7 pounds—the average atmospheric pressure—from the atmospheric line, on the given scale. Each $\frac{1}{8}$ inch on the scale represents a pressure of 5 pounds ($8 \times 5 = 40$). Our measurement then will be not quite $\frac{3}{8}$ of an inch, although in the original diagram that distance was taken as a matter of

convenience, thus making the pressure 15 pounds instead of 14.7, and for all practical purposes this is sufficiently close. The reason that the vacuum line is drawn in is because the calculations involved in connection with pressures deal with those from zero, or "absolute," as it is termed.

We next draw lines at the extremities of the diagram at right angles to the vacuum line, and to a height equal to the boiler pressure (which is given) as measured on the scale, in the same manner as that of locating the vacuum line. The boiler pressure and initial pressure lines are now drawn parallel to the atmospheric line. From these lines, the loss between the boiler and cylinder can be measured, which proves to be 17 pounds drop.

The clearance of the engine from which our diagram was taken is 8 per cent.; we therefore erect a line from and at right angles to the vacuum line, at a distance from the left-hand side of the diagram of 8 per cent. of its length which represents the length of stroke of the engine.

The diagram is next divided into ten equal spaces, with vertical lines drawn through the center of each space. Upon these lines, or ordinates, as they are termed, a scale is laid, and the measurements in pounds obtained. Thus, for every corresponding part of the stroke of the engine piston, we find just what the existing pressure was. The object of so dividing the diagram is to obtain the mean effective pressure (M. E. P.) which acts upon the piston, and from which the power of the engine can be calculated. The total of these measurements is 431, which, divided by 10—the number of measurements —gives a M. E. P. of 43.1 pounds per square inch. The formula for horsepower, H. P. $= \frac{\text{Plan}}{33{,}000}$, is now applied, and we find that nearly 273 horsepower was being developed at the time this card was taken. Of course, it should be understood that it would be better to take measurements and obtain the M. E. P. from a *pair* of cards—those taken from the head and crank ends of cylinder simultaneously—than to take only one card, as we are doing in this article. But, while a higher degree of accuracy could be attained by so doing, the principles and methods involved are the same in either case. In fact, if extreme accuracy be desired, it would be necessary to obtain the M. E. P. of a pair of diagrams by the use of a planimeter. However, the single diagram and the method applied serves our purpose fairly well, and it can be practiced by those who do not possess a planimeter.

So far, we have seen that the engine which the diagram represents develops 273 horsepower with a M. E. P. of 43.1 pounds. But we want to find out how much steam is being consumed the while. We measure the height of the expansion line at the point of exhaust opening and find it to be 50 pounds absolute. By referring to the diagram it will be seen from and to what points this measurement is taken.

Now we are in a position to determine the *weight* of steam discharged per stroke from the cylinder of this engine. By consulting the steam table (table of properties of saturated steam) we learn that the weight of a cubic foot of steam at 50 pounds absolute is 0.1188 pounds. The cubical contents of the cylinder is found to be 6.15 cu ft.

To this result add 8 per cent. (the clearance), giving 6,642 cu. ft. as the total volume of the cylinder.

Again referring to the diagram (Fig. 1) we see that 82 per cent. of the total volume is to be taken when calculating the volume and weight of the steam dis-

charged. The reader will see the reason for so doing when he notes the exhaust opening and closure in relation to the piston travel, as shown on the diagram.

So, continuing, 82 per cent. of 6.642 = 5.44644 cubic feet, and this multiplied by the weight of 1 cubic foot of steam at the given pressure gives 5.44644 × .1188 = .64703 + pounds of steam discharged each stroke.

Reviewing our work briefly, in order to make it perfectly clear to this point, we have:

A slide-valve engine (non-condensing) of these dimensions: 22 inches diameter cylinder, 28 inches stroke, 118 R. P. M., 43.1 pounds M. E. P.,

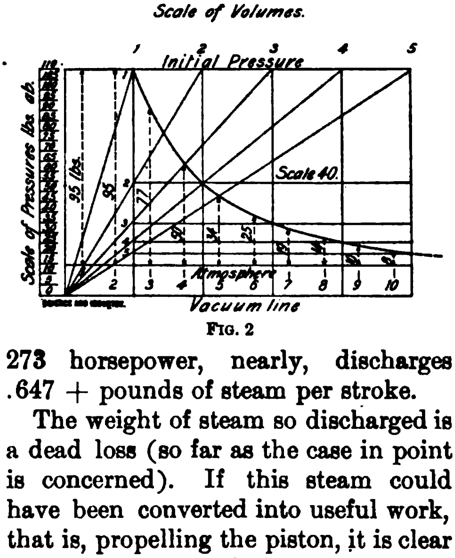

FIG. 2

273 horsepower, nearly, discharges .647 + pounds of steam per stroke.

The weight of steam so discharged is a dead loss (so far as the case in point is concerned). If this steam could have been converted into useful work, that is, propelling the piston, it is clear that less steam would be required to be drawn from the boiler to do the same amount of work, in consequence of which less fuel would be required.

If an engine were constructed without piston clearance, and a valve mechanism which would instantly admit a perfect gas, sharply cut the supply off at a certain part of the stroke, and finally quickly exhaust it at the exact end of the stroke against no pressure greater than that of the atmosphere, we would have an almost perfect machine, that is, so far as the *consumption* of steam is concerned. If an indicator were applied to such an engine, a diagram similar to what is termed "the theoretical," would be produced. The theoretical diagram is never obtained in practice, but it may be constructed and used as a standard of comparison with those that are obtained in practice with a view of determining the relative economy.

We have been working on a diagram which was actually taken from an engine under a given set of conditions. For the sake of comparison, let us construct a theoretical diagram such as could be expected from an engine, working under ideal conditions previously described, of the same power, size, speed, and mean effective pressure, as that of the one which we have just considered.

The theoretical diagram will show us how much gas is required to perform the work under the given conditions, the quantity so determined being the minimum for the given case. The construction of this diagram is based on the law of Boyle, which reads thus: "The volume of a given portion of gas varies inversely as the pressure, the *temperature remaining constant.*"

What we want to do then, is to construct a diagram which shall give the same mean effective pressure as that found in the one just considered, using the same scale and the same data. The figure is made in the conventional way; the point of cut-off is determined by plotting and trial, which in this case occurs at $\frac{1}{5}$ stroke. This is not *exactly* true, as the M. E. P. shown by this card is only 42.7 lb., which is a little less than that desired; so, in reality, the cut-off should occur correspondingly later. While the figure could be plotted to obtain the

exact numerals desired, for the sake of convenience, $\frac{1}{8}$ point of cut-off with its small difference in the M. E. P., is sufficiently close for the purpose in mind.

It is not necessary in this article to go into the details of the construction of the diagram, as a study of Fig. 2 should make it clear how it is made. Having the data given, plotting the point of cut-off to obtain the required M. E. P., drawing in the hyperbolic curve, and then treating the figure as an actual indicator diagram, is the method of procedure.

The pressure at the opening of the exhaust is 21 pounds absolute. The assumed theoretical conditions are that no clearance exists, and owing to the instantaneous entering and exit of the gas in the cylinder, the total volume of the cylinder can be taken when making the calculations.

The volume of the cylinder, as before determined, is 6.15 cubic feet.

The weight of 1 cubic foot of steam (for we will deal with the before mentioned gas as though it were steam for the sake of convenience, although steam does not exactly follow Boyle's law while expanding; the reader will remember that the diagram from which we are now making calculations is constructed from Boyle's law) at 21 pounds absolute is 0.052 pounds, and $6.15 \times 0.052 = .31980$ pounds of steam discharged per stroke under the conditions assumed.

But the slide-valve engine discharged .64700 pounds and the difference is, therefore, .32720 pounds per stroke in favor of the theoretical case. This means a percentage of $50\frac{1}{2}$.

The result just shown would encourage one to install an engine in his plant which would the more nearly approach the theoretical than does that of the engine whose diagram we just considered, if the choice depended principally upon the relative economy. We would therefore naturally turn to the Corliss engine, or one similar to it, to gain our desires.

We will assume that the first engine —the slide-valve—referred to is to be discarded, and a first-class Corliss of the same size and power to be installed instead. A good Corliss engine whose valves are correctly set will produce a diagram which closely resembles the theoretical; the difference is generally so slight that it is fair to use the theoretical with certain modifications, to represent the work done in a fictitious or assumed case. These modifications are the opening and closing

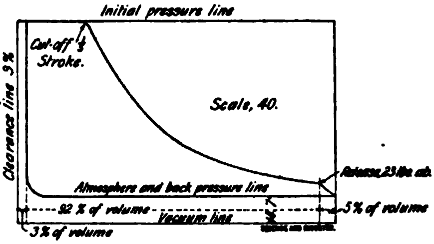

FIG. 3

points of the exhaust valves, as shown on the diagram from those of an actual engine. It will be understood that the expansion line in any engine using steam will not be exactly like the hyperbolic curve in the theoretical, because of the changing temperature of the steam corresponding to the falling pressure throughout the stroke. But we can only assume the theoretical, when constructing a diagram, and the results obtained from calculations will only be slightly different from those obtained from actual practice. In any case, when calculating the steam consumption from an indicator diagram, a due allowance must be made for condensation, leakage, and loss by radiation.

A Corliss engine of the required size,

power, etc. will produce a diagram like that shown in Fig. 3. The figure is constructed in the same manner as the theoretical, except that the exhaust opens and closes somewhat earlier, as shown. The clearance is assumed to be 3 per cent. It is found by measurement of the diagram that 92 per cent. of the total volume of the cylinder and clearance is exhausted per stroke. In order to simplify the figuring, the space occupied by the piston rod has not been considered in any of the cases under consideration.

The terminal pressure in this case is 23 pounds absolute, and the weight of a cubic foot of steam at 23 pounds absolute is 0.056 pounds.

The volume of the cylinder $= 6.15$ cubic feet plus 3 per cent. clearance $= 6.3345$ cubic feet. 92 per cent. of the total volume which is what we are to take $= .92 \times 6.3345 = 5.827740$ cubic feet $=$ the total volume considered; and $5.827740 \times 0.056 = .32635344$ pounds, which is the weight of steam discharged per stroke as accounted for by the assumed indicator diagram.

The slide-valve engine discharged per stroke .647000 pounds of steam, and the Corliss engine .326353 pounds of steam; the difference is .320647 pounds in favor of the Corliss. This means a saving of $49\frac{1}{2}$ per cent.

Each engine makes 14,160 strokes per hour. The slide-valve engine discharges .647 pounds of steam per stroke. $14,160 \times .647 = 9,161.520$ pounds of steam discharged per hour. As the horsepower is 273, $\frac{9,161.520}{.273} = 33.5$ pounds of steam per horsepower per hour is being consumed. According to tests, 25 per cent. might easily be added to this amount to allow for the losses before referred to. This brings it up to nearly 42 pounds per horsepower per hour, which agrees with actual practice.

Again, the Corliss engine discharges .32635 pounds of steam per stroke; and, 14,160 strokes per hour $\times$ .32635 $= 4,621.1160$ pounds per hour. The horsepower is 271; and,

$$\frac{4.621.1160}{271} = 17.05$$

pounds of steam consumed per horsepower per hour. Here we must likewise add 25 per cent. for the losses; this gives us 22 pounds (nearly), which also agrees with the best practice obtained under the best conditions for this kind of an engine. From the foregoing, it can be seen that an engine of the Corliss type will save from 40 to 50 per cent. in steam consumption over that of the common slide-valve engine.

The reader can carry the calculation still further if he wishes, along the same lines and by the same methods, by seeking what further saving may be affected by installing a condensing engine to do the same work.

THE CALCULATION OF RESISTANCES IN SERIES AND IN MULTIPLE

F. H. DOANE

SERIES CONNECTION—MULTIPLE—MULTIPLE SERIES—SERIES MULTIPLE

IT IS often necessary when experimenting with small electrical apparatus to connect a resistance in series with the device, if it is desired to operate the device from an electric-lighting or power circuit. Incandescent lamps form a very convenient form of temporary resistance. It is the object of this article to show how lamps may be grouped and to calculate the resistance of the group taken as a whole. We will consider that

our direct-current lighting circuit has an E. M. F. of 110 volts. We will assume that the ohmic resistance of the device which is under test is 5 ohms and that it consists of a coil of wire in the form of a magnet. We also assume that the only opposition to the flow of current through the coil is due to its ohmic resistance, 5 ohms. A number of arrangements of the lamps will be illustrated and the current flowing through the coil determined.

The simplest connection is the series connection. In this method of connection, the devices connected in the circuit are so placed that the current passed through each, passes successively through the entire circuit and all

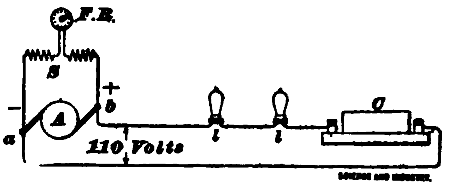

FIG. 1

of the devices connected in on that circuit. Fig. 1 represents a series connection of two lamps and the coil. The terminals of the circuit are connected directly to the 110-volt dynamo terminals. The hot resistance of a 16-candlepower lamp is approximately 220 ohms. The cold resistance is much higher. If such a small current passes through the lamp that the lamp filament is not red hot, the resistance of the lamp is considerably higher than when it is burning up to candlepower. We will, however, make use of the value of the hot resistance in our calculations.

In Fig. 1, A represents the armature of the dynamo, S the shunt field, FR the shunt field rheostat, l, l, lamps, and C the coil. The E. M. F. across the dynamo terminals a, b is 110 volts. There is only one external path for the current to flow from a to b, and that path has the coil and two lamps connected in series in the circuit. Therefore, to find

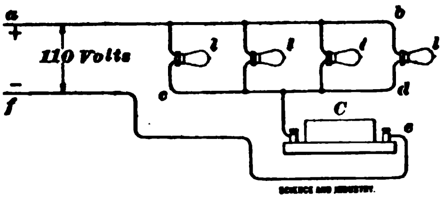

FIG. 2

the current flowing in the circuit, the E. M. F. at the terminals of the dynamo must be divided by the resistance of the circuit, as $C = \frac{E}{R}$, where C equals the rate of flow of current in amperes, E equals the E. M. F. of the circuit, and R equals the resistance of the circuit. The resistance of one lamp is 220 ohms; then, as the two lamps are in series in the circuit, the total lamp resistance will be $220 + 220 = 440$ ohms. The resistance of the coil C is 5 ohms; so, neglecting the resistance of the line wires, the total resistance will be $440 + 5 = 445$ ohms. Then the current equals $\frac{110}{445} = .247$ ampere. The current through the coil would then be .247 ampere. If a larger current were desired, one of the lamps should be cut out, thus leaving a resistance of 220 ohms + 5 ohms = 225 ohms

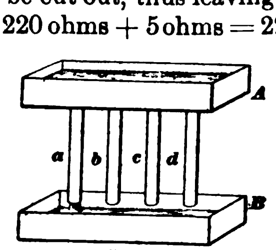

FIG. 3

in circuit. The current through the coil would then be $\frac{110}{225} = .489$ ampere. If instead of two lamps in series, as shown

in Fig. 1, we used 10 lamps in series with the coil, the total resistance in circuit would be $(10 \times 220) + 5 =$

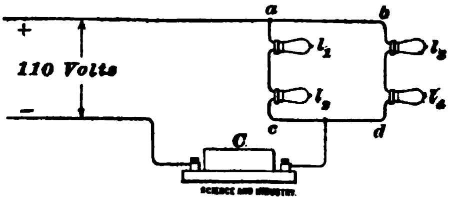

FIG. 4

2,205 ohms, and the current would be $\frac{110}{2,205} = .0499$ ampere. In order to find the current in a series circuit, which contains only ohmic resistances, we add the resistance values of the various devices in circuit and the line resistance, if considerable, and divide the E. M. F. at the terminals of the circuit by this total resistance.

The multiple system is most generally used in electric-lighting and power work. In this system of connection the lamps, or other devices, are individually connected directly across the two line wires. Each lamp connected in between the line wires offers a path for the current to flow from the positive line wire to the negative line wire. Fig. 2 represents four lamps connected in multiple with one another, and the group of lamps connected in series with the coil. In the illustration, *a*, *b* represents the positive line wire, *f*, *e* the negative line wire, and *c*, *d* a wire to which one terminal of each of the four

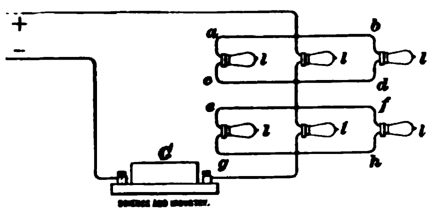

FIG. 5

lamps is connected. The other terminals of the lamps are connected to the positive line wire. The greater the number of lamps connected between *a*, *b* and *c*, *d* the greater the number of paths for the current to flow from the positive line wire to the wire *c*, *d*, which is connected through *C* to the negative line wire *f*, *e*.

Suppose we consider the case of two water tanks, *A*, Fig 3, being 10 feet above tank *B*. Tank *A* is full of water and we allow water to flow from *A* to *B* through pipe *a*; the inlets to pipes *b*, *c*, and *d* are closed. There will be a certain rate of flow of water through pipe *a*. This rate of flow depends on the water pressure, the size of pipe, and the friction between the water and the inside of the pipe. Now, if we allow water to flow down through pipes *a* and *b* we have two paths for the water, and the total path is increased in cross-sectional area. If pipes *c* and *d* are put in service there will be four paths for the water to flow through. Each path has its own frictional resistance, and its own cross-sectional area, but we can consider the four pipes as one large pipe having a cross-sectional area of four times the cross-sectional area of any single pipe and offering only one-fourth of the resistance to the passage of water through it that a single pipe would. The rate at which water is flowing from *A* to *B* would therefore increase as the number of pipes put in service between *A* and *B* increased in number. If the number of pipes is decreased, the rate of flow of water from *A* to *B* is decreased.

In Fig. 2 the four lamps are analogous to the four pipes in Fig. 3. Each lamp path has a hot resistance of 220 ohms. There are four paths. We can consider the four paths as one large path, having a cross-sectional area four times the cross-sectional area of the path through one lamp and having a resistance of one-fourth of the resistance of a single lamp. The joint resistance between *a*, *b* and *c*, *d*

would be $\frac{220}{4} = 55$ ohms. Add to this resistance 5 ohms for the coil and the result will be 60 ohms. This is the total resistance from wire a, b to wire e, f. The current flowing would be $\frac{110}{60} = 1.83$ amperes approximately. If the coil C were cut out and c, d formed part of the line wire e, f, the current flowing in the line wires would be 2 amperes, as $\frac{110}{55} = 2$ amperes. If coil C is in circuit and we turn off two lamps, the resistance between a, b and c, d would be $\frac{220}{2} = 110$ ohms. The total resistance between the two main line wires would be $110 + 5 = 115$ ohms, and the current through coil C would be $\frac{110}{115} = .957$ ampere. If we increased the number of lamps in multiple to 10, the total resistance between the line wires would be $\frac{220}{10} + 5 = 27$. The current through the coil would be $\frac{110}{27} = 4.07$ amperes.

When all of the lamps are of the same resistance, the resistance of a group of lamps in multiple may be found by dividing the resistance of one lamp by the number of lamps in multiple. If the coil or device to be tested has a low resistance compared to the joint lamp resistance, say a resistance of 2 or 3 ohms, the current through the coil can be approximately calculated by allowing ½ an ampere for every 16-candlepower 110-volt lamp connected in multiple between a, b and c, d, Fig. 2.

The joint resistance of lamps, connected in multiple, when the lamps have different resistance values is not so easy to calculate as when the lamps have equal resistances. The joint resistance of two lamps in multiple, one having a resistance of 10 ohms and the other a resistance of 20 ohms can be found by substituting the values of the resistances in the formula, $R = \frac{r_1 r_2}{r_1 + r_2}$. R equals the joint resistance, r_1 the resistance of one of the lamps, and r_2 the resistance of the other lamp. Let $r_1 = 10$ ohms and $r_2 = 20$ ohms, then, $R = \frac{r_1 r_2}{r_1 + r_2} = \frac{10 \times 20}{10 + 20} = \frac{200}{30} = 6.67$ ohms. If these two lamps were connected between a, b and c, d, Fig. 2, the joint resistance between these two wires would be 6.67 ohms. Suppose another lamp of 30 ohms is added in multiple with the 10- and 20-ohm lamps. The joint

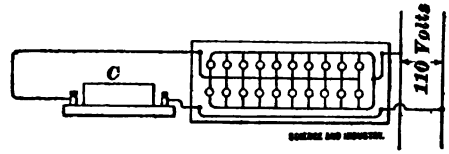

FIG. 6

resistance of the lamps can be found by formula, $R = \frac{r_1 r_2 r_3}{r_2 r_3 + r_1 r_3 + r_1 r_2}$. Let $r_3 = 30$ ohms, then substituting our values we have

$$R = \frac{10 \times 20 \times 30}{20 \times 30 + 10 \times 30 + 10 \times 20}$$

$$= \frac{6{,}000}{600 + 300 + 200} = \frac{6{,}000}{1{,}100} = 5.45$$

ohms. If it is desired to find the joint resistance of a number of lamps in multiple, it can be calculated as follows: Form a fraction for each resistance; the numerator of the fraction is 1 and the denominator is the value of the lamp resistance. Multiply each one of these fractions by the least common denominator, add the values thus obtained and place the sum as the numerator of a fraction which has as a denominator the least common

denominator; then invert the fraction so that the least common denominator becomes the numerator and the sum of the values obtained by adding the products of the multiplication of each fraction by the least common denominator, now becomes the denominator. Reduce the fraction to a whole number and decimal fraction and we obtain the joint resistance of the lamps in multiple.

The connections for the lamps in a multiple-series system are shown by Fig. 4. In order to calculate the resistance between a, b and c, d, add the resistance of lamps l_1 and l_2. This will be the resistance of the path a, c. Now add the resistance of lamps l_3 and l_4. This will be the resistance of path b, d. Paths a, c and b, d are in multiple. If each path has the same resistance, divide the resistance of one path by 2. If the paths have different resistances, find the joint resistance by means of the formula for finding the joint resistance of two dissimilar resistances in multiple. We will suppose all the lamps have a resistance of 220 ohms. Path a, c has a resistance of $220 + 220 = 440$ ohms. Path b, d has the same resistance. Then the joint resistance will be $\frac{440}{2} = 220$ ohms. The total resistance will be 220 ohms $+ 5$ ohms $= 225$ ohms. The current through the coil will then be $\frac{110}{225} = .489$ ampere.

A series-multiple circuit is illustrated by Fig. 5. First find the joint resistance between a, b and c, d. This is $\frac{220}{3} = 73$ ohms. The joint resistance between e, f and g, h is also $\frac{220}{3} = 73$ ohms. As these two joint resistances are in series, we add their values, which results in a lamp resistance of $73 + 73 = 146$ ohms. To this add the resistance of coil C, and the total resistance is $146 + 5 = 151$ ohms. The current through $C = \frac{110}{151} = .728$ ampere.

By varying the number of lamps used and the manner of connecting them, a very great range of lamp resistances may be obtained and the current in coil C varied. In place of lamps, other kinds of resistances may be used, such as resistance coils, wire rheostats, and water rheostats, for the purpose of regulating the current through C.

Fig. 6 illustrates the connections for a lamp bank. Take a small piece of board and mount on the board a number of lamp sockets, either key or keyless. Insert lamps in the sockets. The connections of the lamps are shown in the illustration. The two binding posts on one end of the board are connected to the mains. The two binding posts on the other end are connected to the coil C, or other device to be tested. By turning lamps on or off, the current through C is varied.

MECHANICAL STOKING

GEORGE E. WALSH

MECHANICAL stoking apparatus has received practical tests in many of the large steam plants throughout the country in the past few years, but it is only comparatively recently that general satisfaction has been obtained. On our mammoth steamers mechanical stoking, for one reason and another, has not yet reached the point of development which enables the companies to dispense with the large number of stokers. Such steamers as the Oceanic and Celtic carry with them an army of nearly a hundred stokers,

whose sole duty is to do the work which mechanical apparatus performs on land. There is a disposition in marine architecture to sacrifice nearly everything for speed, and the great racing liners have not always been built with the most careful attention to economy of operation. However, there is a change now toward the construction of steamers with enormous carrying capacity and less speed, with corresponding economy of operation.

Mechanical stoking has never proved as pliable and efficient under emergencies as stoking by hand, but the greater economy obtained thereby has made most progressive steam plants adopt it in spite of its drawbacks. In the latest improvements in this sort of apparatus something like human efficiency has been obtained, and the equipment of the modern steam plants with mechanical stokers is rapidly taking place. In fact, it is believed now by the most competent engineers that better actual results are obtained in this way than with ordinary hand firing. With properly constructed mechanical stoking apparatus the flue gases can be better regulated, and also the temperature of the boiler. Naturally the feeding of the fire can be carried on quicker and more uniformly, and the amount of air admitted to the fire is under perfect control, which in turn produces better combustion.

There are several types of mechanical stokers in use, but for the most part they are constructed on the same principles. One of the finest plants in the country for studying the practical value in operation of modern stoking apparatus is the large power house of the Metropolitan Street Railway Co., of New York, and in a short time the Manhattan Elevated Railway Co.'s new power house will be equipped with even a greater number of mechanical stokers. In the former plant there are installed 384 modern stokers which feed the furnaces to heat 96 boilers of over 50,000 horsepower. The stokers are operated by small engines, and their construction is such that they produce most satisfactory results. The chief engineer of the company claims that they perform their work so well that the fires can be kept in better condition than by the old system when hand stoking was employed. A feature of the system adopted makes the entire bed of fire visible from a point under the grate, where clinkers, as they form, can be seen and dislodged. This can be done without opening the doors and letting in more air. The removal of the clinkers in this way is an important consideration where almost perfect combustion is desired and where the highest possible heat efficiency is necessary at all times. In a similar way any uneven burning of the coal in the grate cannot only be detected from the outside, but in nearly all cases it can be instantly corrected without injuring the fire. The lack of uniform burning of coal is a source of considerable loss of efficiency in many grates, and the impossibility of always detecting this in time to prevent its spread is an expensive drawback. To overcome this is consequently no small gain.

There are two important gains made by the mechanical stokers in the practical tests so far made in the enormous plant of the Metropolitan Street Railway Co. One is a considerable saving of labor and its cost, and the second a great improvement in the efficiency of the stoking. The first is a considerable item, representing fully 30 to 40 per cent., and the latter is one that cannot be expressed in dollars and cents so easily, but which, none the less, is quite evident to the operators.

The simple operation of the modern

mechanical stokers is such that any experienced fireman can manipulate them without trouble. The stokers of the Metropolitan Co. are of the Roney type. There is a hopper for receiving the coal, a set of rocking grates, and a dumping grate. The coal is put in the hopper, which feeds it as needed to the grate, which is inclined at an angle of 37 deerees. The rocking grate moves through an arc of 15 degrees, and the grate bars and the pusher receive a corresponding movement from the agitator connected by an eccentric shaft attached to the stoker in front.

The pusher can be regulated to suit the needs of the fire, and has an adjustable mechanism which can be arranged independent of the rest of the machinery. Likewise the grate bars can be adjusted to almost any movement desired. They are divided into two parts, and each grate bar is easily accessible from below, so that if any trouble develops, it can be reached without difficulty.

The mechanical stokers are of the enclosed type, so that they are protected from all dust, ashes, and dirt, and their cleaning is very simple, while every part can be taken out and replaced without deranging the whole mechanism of the plant. The steady movement afforded by their freedom from all dirt and dust may not be disturbed for months at a time. There is provision for nearly all clogging and troubles that develop in ordinary grates. Even the engines which control the movement of the stokers are run in a bath of oil, and also the worm and worm-gear. The complete housing of the engine and worm and worm-gear makes operation simple and clean throughout. The automatic lubrication of the different parts of the machine is so well arranged that the surplus oil and dirt is carried out where a cleaner can very easily remove it.

Not the least important part of these improved mechanical stokers is their simplicity. Descriptions might indicate a complexity of construction that would render any disarrangement an expensive matter to repair, or their operation a matter of a good deal of skill. But, on the contrary, they are so simple in design and construction that comparatively little skill and experience are required to take one apart and put it together again. An ordinary engineer understanding the first principles of machinery would have little difficulty in changing, cleaning, or readjusting any one of the mechanical stokers. The work of taking care of the stokers is entrusted to the ordinary fireman, who actually performs the work of nearly a score of human stokers.

Anthracite coal is used in the Metropolitan Railway Co.'s plant, and also in several other large ones in New York equipped with the mechanical stokers. Guards are provided to regulate this coal when fed in different sizes, and when the small coal slides down toward the grate, it can be held back to suit the convenience of the fireman. When the dumping grate is down for the purpose of removing clinkers or ashes, the guards can be adjusted so that the small coal is held back. Otherwise it would slide down and cause trouble.

The numerous recent improvements in the mechanical stokers for heavy work have brought them to a point of efficiency which practically insures their general adoption in most large steam plants, or where steam is merely used as an auxiliary for generating and distributing electric power. In the movement to reduce the cost of producing electric power by means of small steam engines, the mechanical stoker has in recent years played a most important part. The modern fireman

must be proficient in the operation of the mechanical stoking equipment, for the duty of handling and caring for the mechanism is becoming a part of the work which he is employed to perform. Unless he understands the different types of stokers, and knows how to manipulate, adjust, clean, and even repair the machinery, his services will be in less demand.

EDITORIAL COMMENT

The thirty-second annual commencement of the Worcester Polytechnic Institute was held from June 8 to June 12, inclusive, at Worcester, Mass. The annual commencement lecture before the Washburn Engineering Society was given in the lecture room of the engineering laboratory by Dr. A. A. Duff, professor of physics at the institution. His subject was "Wireless Telegraphy, the Telephone, and the Telephonic Arc Light."

The annual outing of the Pennsylvania Editorial Association was held at Cambridge Springs, Pa., from June 17 to 24, inclusive. There were about 150 members present, and the outing was voted a complete success in every particular. For the many kindnesses extended to them, the thanks of the members are due to the local committee of arrangements of Cambridge Springs, and all those who assisted in making the outing the success which it was.

We frequently receive letters from our subscribers requesting that we publish articles on certain subjects, and whenever the subjects mentioned come within the proper scope of the magazine we do so. But oftentimes the subjects mentioned are of interest to only a limited number of people, and when this is the case we cannot publish articles on them to the exclusion of other matters of more general interest.

Then again, it must be remembered that SCIENCE AND INDUSTRY is a magazine for steam engineers. We believe that we can publish a better magazine by thoroughly covering one branch of engineering than by touching on them all to a greater or less degree. In this advanced age of progress the great majority of steam engineers have more or less electrical machinery under their control, and it is necessary that they should understand how to handle it, so that many articles on electrical subjects which might at first appear out of place, are perfectly suitable for a steam engineering magazine.

Civil engineering, municipal engineering, etc. are entirely foreign to the profession of steam engineering, and we cannot aim to cover them in this magazine.

Our supplement this month consists of a table giving the current required by motors ranging from one to two hundred horsepower. Figures are given both for direct-current motors and for single-phase, two-phase, and three-phase alternating-current motors of 110, 220, and 500 volts.

Judging from the number of letters we receive asking for information on this point the table will be found a valuable reference by many of our readers.

BOOK NOTICES, CATALOGUES, AND TRADE NOTES

FIVE YEARS' QUESTIONS AND ANSWERS, as originally published in The National Engineer. Price $2.00.

As the title indicates, this book is a collection of questions and answers published in the official organ of the National Association of Stationary Engineers for the past five years. It consists of 244 6 × 9 pages, with 50 illustrations, printed on heavy paper in good-sized type and is bound with silk cloth. This book is a credit to the N. A. S. E., to the educational committees of the past five years, and the committee on compilation. The answers to questions are in plain language, not varnished by unnecessary mathematical gymnastics, but just as one engineer would answer another. The topics treated in question-and-answer form are as follows: Boilers, furnaces, fuel, combustion, chimneys, etc. Compressed air, heat value of different fuels, steam engines, indicator practice, shafting, belting, etc. Pumps, compressors, hydraulics, refrigeration, heaters, condensers, injectors, etc. Dynamos, motors, wiring, etc. Technical mathematics, science, mechanics and physics.

THE ELECTRICAL CATECHISM. Compiled from the regular issues of Power. Published by the Hill Publishing Co., New York. Price $2.00.

There is no question but that books of this kind are of great assistance both to those desiring general instruction and those seeking information on some particular point. The Electrical Catechism contains 533 answers to practical questions about electrical apparatus. The information is given in a clear and concise manner and the ground is thoroughly covered. The book is well gotten up and profusely illustrated.

DIRECTORY OF AMERICAN CEMENT INDUSTRIES AND HAND BOOK FOR CEMENT USERS. Edited by Charles Carroll Brown, M. Am. Soc. C. E. Published by Municipal Engineering Co., Indianapolis, Ind. Price $5.00.

The Hand Book contains information regarding the quality of cements, specifications governing the acceptance of shipments, specifications and instructions for their use in all kinds of structures, estimates of cost of work, freight rates, and materials and processes used in making cement in all the works in this country. The Directory contains information concerning the cement trade. It gives full information regarding all American cement manufacturers, including location, officials, capitalization, credit, capacity, amount of cement manufactured, names of brands, and railroads on which works are situated. It has a descriptive list of all the brands of American cements, giving statement of kind of cement, whether Portland, natural hydraulic or puzzolan, manufacturers and principal sales agents, and a list of general sales agents with statement of companies and brands for which they act as distributors, with credit rating and estimate of amount of cement handled each year. The foreign cement trade is represented by an alphabetical list of companies manufacturing cement, and brands exported, classified by countries, and a list of foreign importers and exporters, similarly classified. The book will unquestionably be of great value to all those interested in the cement industry.

We are in receipt of a booklet from the Keystone Chemical Manufacturing Co., of Camden, entitled "Worth Knowing," a careful reading of which shows the application of the title to the contents. The book not only describes their product, tri-sodium phosphate boiler compounds, their effect upon feedwater, clearing and purifying it before entering the boilers, their action in preventing the formation of scale, and the dissolution of same where formerly deposited, but it gives a large variety of useful information pertaining to steam and kindred topics that is well worth knowing to those interested in that subject. Tri-sodium phosphate has the full endorsement of the leading boiler insurance companies. The book is not for general distribution, but is sent free of charge to steam users in general, particularly to the chief engineer and those interested in securing the best results from their boilers.

We have received a neat folder used by the Hetterschied Mfg. Works, Grand Rapids, Mich. The folder contains excellent cuts of their drawing and typewriter tables with full descriptions of both.

The Stephenson Mfg. Co., Albany, N. Y., send us a neat folder descriptive of their line of force-feed cylinder lubricators, Rollin's flue cleaners, and boiler compound, and Stephenson bar belt dressing.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

MECHANICAL

(207) Please name some engineering journal containing a description of the Parsons turbine and giving illustrations showing its construction.

H. P. L., Huntsville, Ont.

ANS.—See SCIENCE AND INDUSTRY for July, 1902.

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(208) Please give me the name of an up-to-date book on combustion, treating all kinds of fuel. J. E. E., Boston, Mass.

ANS.—See a book recently published on this subject entitled "A Catechism on the Combustion of Coal," by William M. Barr Published by N. W. Henley & Co., New York. Price $1.50. This can be obtained from the Technical Supply Co., Scranton, Pa.

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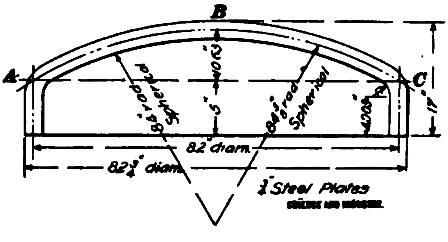
(209) Please give me the name of a good book on steel and how to work it. I want a book dealing with the qualities and adaptability of the different carbon steels for different purposes.

W. H. W., Carpentersville, Ill.

ANS.—The best book we know of on this subject is one entitled "Steel—A Manual for Steel Users," by William Metcalf price $2.00. This can be obtained from the Technical Supply Co., Scranton, Pa.

(210) Please give through "Answers to Inquiries" column in SCIENCE AND INDUSTRY the correct method for determining the diameter of a circular plate to form the bumped boiler head shown in accompanying sketch. G. J. W., Philadelphia, Pa.

ANS.—The correct blanks for plates of any thickness in boiler work may be determined by calculations based on the central line of the material. The dimen-



sions given in the figure, therefore, are assumed on this line, which is indicated by the dotted line in the drawing. It is first necessary to find the area of the bumped portion—that is, the area of the circular zone *A B C*. This is done by multiplying the height of the zone by the circumference of the great circle of the sphere of which the zone is a part, or $3.1416 \times 168\frac{3}{4} \times 10.63 = 5{,}636+$. To the product thus obtained must now be added the area of the circular ring that forms the flange of the boiler-head, or $82 \times 3.1416 \times 5 = 1{,}288+$. Adding, $5{,}636 + 1{,}288 = 6{,}924$, the area of the circular blank for which we must now find the diameter. Since diameter $= \sqrt{\frac{\text{area}}{.7854}}$, we find the required diameter to be, approximately, 93.9 inches. The method here employed is based on the supposition that the blank, after forming, or bumping, is practically unchanged so far as the thickness of the material is concerned. If the work is done in a hydraulic press the method here described will prove very satisfactory.

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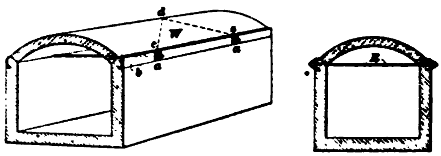
(211) The accompanying sketch shows a brick flue, the horizontal thrust of the arch being taken by the tie-rods *a a*. These tie-rods are about 8 feet apart, and pass through a channel iron skewback, as at *b*, on each side of the flue. When making the calculations for the size of the channel iron skewback necessary to carry the strain between the tie-rods, a debate arose as to whether

the skewback should be proportioned for the side thrust caused by the weight of a triangular section, as at *c*, *d*, *e*, or whether it did not have to withstand the weight of the entire arch between *c* and *e*. Would you kindly give me your opinion regarding the subject?

W. D. VAND., New Brunswick, N. J.

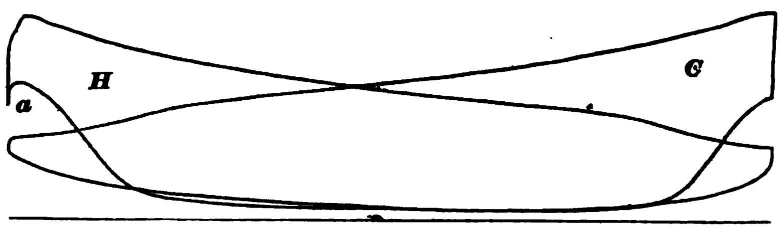
ANS.—Undoubtedly, if the arch is of brick, in which all transverse joints are broken, and the bricks are laid in good cement mortar, the cohesiveness of the mortar would



tend to create a rigid arch of masonry, which would act similar to the Gustavino construction, or as an egg shell, and in consequence the thrust upon the channel would be somewhat reduced from the thrust created by a theoretical arch. In all considerations of arches, however, the adhesiveness of the mortar, which, being more or less of an unknown quantity, is neglected, and the arch is considered as elastic, being held in equilibrium by the horizontal thrust at the skewbacks, the loads upon its crown, and the compression in the ring. We would proportion the channel bar for the thrust due to the theoretical arch, and would not consider only that portion of the arch included in the triangle *c*, *d*, *e*, but would consider a section of the vault included between *c* and *e*, allowing the adhesiveness of the mortar and the resistance of the side walls as additions to the factor of safety.

***

(212) The accompanying indicator card is taken from a 12″ × 24″ engine making 112 revolutions per minute. The scale of the spring is 40. The back pressure is due to exhausting into a heating system. The engine is driving a 22½ K. W. dynamo. (*a*) What horsepower is being developed? (*b*) State the cause of the drop in the compression line at *a*. (*c*) What changes, if any, are advisable in the valve setting?



A. P., Beaver Falls, Pa.

ANS.—(*a*) We find by means of the planimeter that the area of the head-end diagram is 2 square inches. The area of the crank-end diagram is 2.24 square inches. This makes the average area 2.12 square inches, and we find, by measurement, that the length is 4 inches. The length of the average ordinate is found by dividing the area by the length of the diagram which gives $\frac{2.12}{4} = .53$ inches. The M. E. P. is obtained by multiplying the length of the ordinate by the scale of the spring, which gives 40 lb. × .53 = 21.2 pounds. The area of the piston is 113.1 square inches. The length of stroke is 2 feet, and number of strokes is 224. The indicated horsepower may be obtained by substituting in the following formula: I. H. P. $= \frac{plan}{33,000}$. In this formula $p =$ M. E. P., $l =$ length of stroke, $a =$ area of piston, and $n =$ number of strokes per minute. Substituting, we have

$$\text{I. H. P.} = \frac{21.2 \times 2 \times 113.1 \times 224}{33,000} = 32.55.$$

This is the number of horsepower that the engine was developing *at the moment the diagrams were taken.* (*b*) When the compression line drops as shown at *a*, it indicates that the pressure in the compression space has fallen, and this can only be caused by a steam leak passed the valve or piston. (*c*) The rounded corner where the steam line and admission line meet, is caused by the engine beginning the forward stroke before full pressure is admitted to the cylinder. This indicates the absence of lead. Since the lead on the other end appears to be ample, it is probable that equalizing the lead by moving the valve on the valve stem, is the only adjustment that is required.

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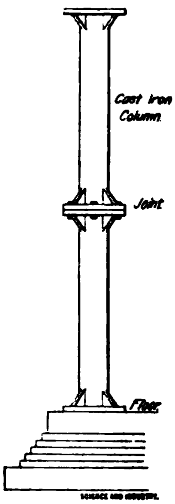
(213) If 2 columns are superimposed, as in the accompanying figure, and the strength of each is known, how can their combined strength be ascertained, and how shall a connecting flange and bolts be proportioned?

B. P. C., Jersey City, N. J.

ANS.—If there is no floor construction at the connection, the column may be considered as a single column, having a length equal to the combined length of the 2 columns, because if the joint is rigidly bolted, the flange and brackets will rather tend to increase the strength of the column

under lateral deflection, as they reenforce it at the weakest point, provided the combined length of the column is not greater than 30 times its least dimension. We would apply the usual formula for determining the strength of a cast-iron column having flat or square ends. In this formula the allowable bearing strength of the column in pounds per square inch of section is represented as s, and



$$s = \frac{s_1}{1 + \left(\frac{l^2}{3,600\, R^2}\right)}$$

in which s_1 equals the allowable compressive strength of cast iron in pounds per square inch, l the length of the column in inches, and R the least radius of gyration. The least radius of gyration for a hollow cylindrical cast-iron column is obtained by the formula $\frac{d^2 + d'^2}{16}$, in which d equals the outside diameter of the column and d' the inside diameter. The allowable unit bearing value for cast iron is usually taken at from 10,000 to 20,000 pounds, depending upon the factor of safety desired. In applying this formula we would consider that for a 10-in. or 12-in. column there were spaced at least 6 1-in. bolts around the flange holding the 2 columns together. If there is any doubt as to the resistance of the column, the moment of inertia of the combined section of all of the bolts holding the flanges together could be figured and from this moment of inertia the resisting moment of the bolt sections alone could be determined. If this resisting moment equals the resisting moment of the normal column section, a sufficient number of bolts has been assumed, but if the bolts do not give a sufficient resisting moment, then their number should be increased. In figuring the moment of inertia, it should, in our opinion, be calculated about an axis through the bolt center of the flange.

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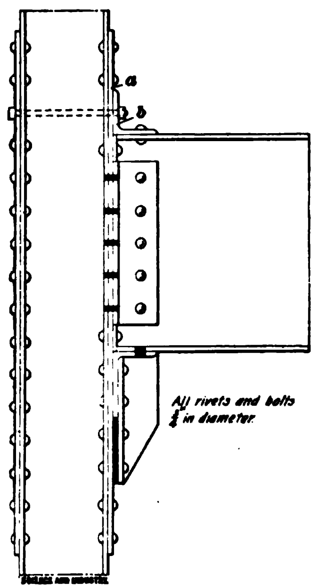
(214) (a) What kind of a bracket would you design for a 20-inch, 65-pound I beam? The beam is to be fastened to the flanges of an 8-inch channel column, and is to carry a uniform load of 40 tons on a span of 15 feet. (b) Please show how to figure the bearing surface of the beam, and explain the effect on the web when placed as shown on the accompanying sketch. (c) What is the tendency of the web to crush or buckle over the bearing? L. L., Allegheny, Pa.

ANS.—(a) The load upon the beam is great, and the reaction at the support is equal to 40,000 pounds. It would consequently be advisable to design the connection as shown in the figure. At a is shown a reenforcing plate securing the two channels together, and stiffening the column at the point of application of the load. A rigid connection is made to the plate by means of the angle bracket beneath, and the angle clips riveted to the web of the girder. It is customary in designing such connections to provide angle clips, secured to the top flange of the girder and bolted through the column, as designated at b. In this way the leverage of the connection is increased and the lateral rigidity of the joint improved. The design shown in the figure is all that is required to resist the load. (b) There is no danger of the bearing surface of the beam being insufficient, for several square inches of surface is necessary for any connection that can be designed, and this is sufficient for its portion of the load, great as it is. (c) There is no danger of the web crushing or buckling from the bearing if the allowable shearing stress per square inch does not exceed the value of S in the following formula: $S = \frac{12,000}{1 + \frac{h^2}{3,000\, t^2}}$, in which formula S equals the allowable shearing stress per square inch, h equals the depth of the web between the flanges of the girder, and t the thickness of the web, both of these values being in inches. The thickness of the web of the beam mentioned in your inquiry is ½ inch, and the depth or height between



the flanges is approximately 18 inches; then by substitution in the formula,

$$S = \frac{12{,}000}{1 + \frac{324}{3{,}000 \times .25}} = 8{,}380.$$

Consequently, the area of the girder is equal to 19 square inches, and, using the allowable shearing value as obtained by the formula, its resistance to crushing or buckling would equal $8{,}380 \times 19 = 159{,}220$, which is greatly in excess of the reaction at the end of the girder; besides, if the connection shown in the figure is used, the web is greatly reenforced by the angle clips.

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(215) (*a*) Will you please explain how the amount of the horizontal stress at the skewback of the brick arch shown in Fig. 1 is obtained? (*b*) Will you also explain the best method of resisting this thrust, and give

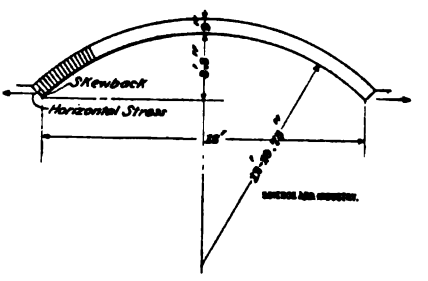

FIG. 1

the size of a horizontal trussed I beam necessary to resist the same, providing such construction is used at the abutment? The length of the arch is 24 feet.

H. M. R., Findlay, Ohio.

ANS.—(*a*) The amount of the horizontal thrust at the abutment of an arch symmetrically loaded, may be obtained by the formula $Q = \frac{X \times W}{r}$, in which Q equals the horizontal thrust of the arch in pounds, X equals, with reference to Fig. 2, one-half of the theoretical span minus the distance c, while W equals the load upon one-half of the arch in pounds, and r equals the theoretical rise of the arch. In calculating the horizontal thrust at the abutment at any arch, it is usual to consider a slice through the arch 1 foot in width, for by so doing all surface measurements then represent volume. From Fig. 2 it is first desired to calculate the distance c, which is the distance that a vertical line passing through the center of gravity of the load upon the haunches of the arch is located from the center line of the arch. This distance c may be determined by the following rule: Find the sum of the products of the area of each elementary section, multiplied by the perpendicular distance between its center of gravity and the center line of the arch; divide this sum by the total area of the load; the result will give the required distance c. This is equivalent to dividing the load w, x, y, z into any number of equal divisions horizontally and multiplying the area of each of these divisions by the distance from its center of gravity to the center of the arch. In the case of Fig. 2, the area e would be multiplied by a_1, the area d by b_1, the area c by c_1, etc., so that the sum of these areas, by their respective distances from the center line of the arch, will be as follows:

e =	4.58 ×	.91 =	4.18	
d =	4.89 ×	2.83 =	13.84	
c =	5.91 ×	4.83 =	28.54	
b =	7.58 ×	6.66 =	50.48	
a =	9.97 ×	8.5 =	84.74	
Total area =	32.93		181.78	sum of products

According to the rule, by dividing the sum of the products by the sum of the areas, or $181.78 \div 32.93$, the distance c is found to equal 5.52. Since from Fig. 2 the theoretical half-span is equal to 9′ 3″ or 9.25, and the distance c is equal to 5.52, the distance X will equal $9.25 - 5.52 = 3.73$. Before the value Q in the formula given for obtaining the horizontal thrust can be found, it is necessary to know the weight of the load included in the elementary sections a, b, c, d, etc. The total volume of the load upon one-half of the arch when the load and the arch is considered 1 foot thick, and when the masonry is assumed to weigh 120 pounds per cubic foot, is equal to 32.93×120, or 3,952 pounds. From this calculation the $X = 3.73$ feet, $W = 3{,}952$ pounds, and the

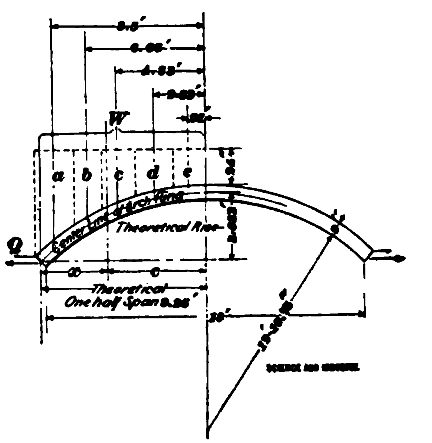

FIG. 2

theoretical rise or $r = 3.833$ feet. By substituting in the equation $Q = \frac{X \times W}{r}$, it becomes $\frac{3.75 \times 3{,}952}{3\ 833} = 3{,}867$ pounds, the

amount of the horizontal thrust at the abutment of the arch, this being the thrust for each lineal foot of arch, the entire thrust of the arch being equal to this amount multiplied by the length of the arch. As no load was given in connection with the arch shown in Fig. 1, it was necessary to assume the load shown in Fig. 2. By the method given you will be enabled, however, to calculate the thrust for any load. If the arch has only itself to support, consider the load as equal to the weight of the arch, and make the calculations as given above. (*b*) The best way to resist the horizontal thrust of such an arch is to use tie-rods at intervals, but we judge that the arch in question is used in the construction of a furnace or kiln, and consequently such rods are not permissible. If the sides of the vault are low, the thrust could be resisted by heavy masonry abutments, and these should be calculated to resist the over-turning moment produced by this horizontal thrust. If you use tie-rods at the ends holding heavy cambered beams in a horizontal position, we would advise the use of two 10″ 30-pound I beams side by side, supported by a camber rod at two points, dividing the span of the girder into three equal parts. The camber rod will of necessity be $2\frac{1}{4}$ inches in diameter, and upset on the ends to $2\frac{3}{4}$ inches. If some allowance is made for the resistance of the sides of the vault in assisting the trussed beam to sustain the thrust, it is probable that a $2\frac{1}{4}$-inch camber rod upset to $2\frac{1}{2}$ inches would meet the requirements; the buckstay rods through the end of the girder must be at least $1\frac{3}{4}$ inches in diameter, upset to 2 inches.

ELECTRICAL

(216) How is fuse wire soldered to copper terminals? My difficulty is to make the solder take to the fuse metal with acid flux.

H. R. L., Huntsville, Ont.

ANS.—You might try a solution of rosin in alcohol, though as a general rule the acid flux is easier to work with. We do not see why it fails in the case you mention unless the fuse wire is unusually greasy. If such is the case try dipping it in a solution of caustic soda to remove the grease.

***

(217) I wish to know where I can get the book mentioned in Question No. 70, March SCIENCE AND INDUSTRY, giving Hertz experiments on electrical phenomena.

O. B. P., Lebanon, Pa.

ANS.—The book referred to is "Electric Waves," by H. Hertz, translated by D. E. Jones, with a preface by Lord Kelvin. It contains the researches of Hertz on the propagation of electric action (waves), with finite velocity through space. You can obtain this book from the Technical Supply Co., Scranton, Pa. The price is $2.50.

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(218) (*a*) What kind and size of battery should I use for an annunciator where the push button is $\frac{1}{2}$ mile distant? The line is No. 12 galvanized iron wire? (*b*) Are 4-ohm magnets the right size? Does it make any difference whether the battery is located at the push or at the other end?

I. G. W., Union City, Mich.

ANS.—(*a*) Much depends upon the character of the ground connections if you use a ground return circuit. If a grounded circuit is used you would likely need at least 10 Leclanché cells. If you use a metallic circuit 6 or 8 cells should be sufficient. (*b*) Yes. (*c*) No.

***

(219) (*a*) What is the correct reading of a wattmeter that registers in watt-hours when a 16-candlepower lamp burns for 10 hours on a 100-volt circuit? (*b*) When a current of 1 ampere flows for 1 hour at a pressure of 100 volts, is it equivalent to 1 watt-hour? W. F. S., Herkimer, N. Y.

ANS.—(*a*) The reading will depend somewhat on the efficiency of the lamp. Assuming 3.5 watts per candlepower as a fair current consumption, the lamp would take $16 \times 3.5 = 56$ watts. Consequently, if it were burned for 10 hours, it would use 560 watt-hours, and if the meter started from zero the hand of the first dial would be a little over midway between the fifth and sixth divisions. (*b*) No, it is equivalent to 100 watt-hours, because 1 ampere at 100 volts is equal to 100 watts, and if the current flows for 1 hour the total expenditure of energy is 100 watt-hours.

***

(220) I am using woven wire brushes on a Westinghouse shunt-wound bipolar dynamo 110 volts, 350 amperes. The brushes are $\frac{5}{16}$ inches $\times$ $\frac{1}{4}$ inches, and the brush-holder is 3 inches from the commutator. I wish to make a change and get something better. I have alwaye had considerable trouble from sparking. Is there a carbon brush on the market that will answer?

I. K. H., Chester, Pa.

ANS.—Carbon brushes would undoubtedly give better service as regards sparking, but it is hardly practicable to use them in this case because they would run too hot, the collecting surface of the commutator being designed for copper brushes. You might try a set of Wirt high-resistance brushes. These can be obtained from almost any large supply house. They will conduct the large current better than the carbon and they may help in suppressing sparking.

***

(221) (*a*) Please explain why the current generated by a jump-spark coil jumping $\frac{1}{2}$ inch does not hurt a person as much as a

500-volt direct current. Have the amperes anything to do with shocking a person? (*b*) Why does static current generated on a belt not hurt a person? (*c*) What causes a groove, similar to that made by a chisel, when lightning strikes a tree? W. F. L., St. Joseph, Mo.

ANS.—(*a*) and (*b*) The severity of the shock depends upon the volume of the current as well as the pressure. In both these cases the volume of current is very small. (*c*) This is sometimes explained by attributing it to the explosive action caused by the sudden conversion of the moisture in the wood into steam. A lightning discharge is of large volume, hence its heating effect is large. Like most of the effects of lightning, the exact nature of the phenomenon is not well understood. Some authorities claim that the groove is caused simply by mechanical disintegration due to the discharge. In many cases the tree is shattered and no well-defined groove is cut.

***

(222) I have always considered a Gramme wound armature a little out of date, but at an electrical works where I am employed they still use this style of winding to some extent. (*a*) Has this style of winding any advantages over the drum or cylinder armature? (*b*) Does the steel wire used as the bands on an armature have a noticeable effect on the lines of force passing through it? If the steel wire brings about bad results, what should be used instead?

F. G. F., Erie, Pa.

ANS.—(*a*) The ring armature is advantageous for machines generating high pressure, as for example arc light dynamos. One advantage is that the coils can be very thoroughly insulated and a coil can be removed for repairs without disturbing neighboring coils. The ring armature is also useful for small, slow-speed machines having armatures of large diameter, but for the great majority of direct-current dynamos the drum winding is preferable. (*b*) The steel bands would not likely have an appreciable effect on the magnetic field, although they would produce some leakage from pole to pole. Steel is not generally used for the bands that come under the pole pieces. It is better to use phosphor bronze, as there is a considerable hysteresis loss in hard steel wire.

***

(223) A certain plant is used to light a building. It is desired to light another building 800 feet away and using 1,000 lamps. In order to save copper, 115-volt lamps are used in the first building and 100-volt lamps in the second building. At 15 cents per pound, how much less would the copper for the mains cost with 100-volt lamps in the second building than with 110-volt lamps? E. N., Schenectady, N. Y.

ANS.—With 115-volt lamps in the second building the drop in the line is $115 - 100 = 15$ volts. Allowing $\frac{1}{2}$ ampere for each lamp and assuming that the two-wire system is used, the current would be $\frac{1,000}{2} = 500$ amperes. The cross-section of wire required can be obtained from the formula,

$$\text{Circular mils} = \frac{21.6 \times \text{distance in feet} \times \text{current}}{\text{volts drop}} = \frac{21.6 \times 800 \times 500}{15} = 576,000 \text{ cir. mils.}$$

Suppose a 550,000 circular mil cable were used. This would weigh 4,630 pounds per 1,000 feet, and as 1,600 feet would be required, the total cost would be

$$\frac{4,630 \times 1,600}{1,000} \times .15 = \$1,111.20.$$

In the second case the drop would be $115 - 110 = 5$ volts, because 110-volt lamps are used in the second building. Since the drop is one-third as great, three times the quantity of copper will be needed, hence the cost would be $3,333.60 and the saving by using the 100-volt lamps would be $2,222.40. The above assumes that the 110-volt and 100-volt lamps take the same current. This is not strictly correct, but the difference is hardly sufficient to greatly affect the final result.

***

(224) In the May number of SCIENCE AND INDUSTRY, "Answers to Inquiries" No. 138, (*a*) What is meant by the front and back pitches? (*b*) Why is the armature called wave-wound? (*c*) What advantage is there in so winding an armature? (*d*) I have noticed a 4-pole motor having only two brushes. How is this made possible? Could it be brought about by using a wave-wound interpolated-segment armature? (*e*) How is the ringing of the bell at a railroad station, which announces the approach of a train, brought about?

W. E. T., Waltham, Mass.

ANS.—(*a*) By the back pitch is meant the number of winding-spaces passed over on the back of the armature when connecting up the coils. For example, if one side of a coil lies in winding-space No. *1* and the other in winding-space No. *10*, the back pitch would be 9. The front pitch is the number of winding-spaces passed over when connecting up the front ends of the coils. If the winding were carried from a bar, down space *1*, across the back to *10*, up *10* and then to another bar, thence down *17* etc., the front pitch would be from *10* to *17*, or 7. (*b*) The armature is called wave-wound because the winding progresses around the armature in zigzag or wave fashion. That is, after a coil has been traversed the winding does not come back to the next adjacent bar but progresses on around the armature, and $\frac{p}{2}$ coils are connected in series before the bar next to the

starting point is reached, p being the number of poles on the machine. (*c*) and (*d*) This type of winding is well adapted for fairly high voltages or for machines where the current output is not very large. All wave-windings have the advantage of requiring but two brushes whether they are used with interpolated segments or not. There are only two paths for the current through the armature, hence but two brushes are needed. This is a decided advantage in the case of railway motors, where the two lower brushes would be hard to get at. (*e*) This is usually accomplished by insulating a section of the track and arranging the connections so that when the train runs on to the section contact is established by means of the wheels and axles, thus causing the bell to ring until the train runs off the section.

***

(225) (*a*) Please explain the various operations necessary for (1) throwing one machine in step with another; (2) dividing the load equally between each machine; (3) transferring load from one machine to another. The machines are S. K. C. 1,200 volts, 300 kilowatts, driven by waterwheels with Lombard governors. (*b*) What harm might be done if these operations were not properly carried out? (*c*) If, on one of the above generators, the load on one leg was 75 amperes, on the other 80 amperes, voltage 112, what should the exciter ammeter and voltmeter indicate?

I. R., Severn Bridge, Ont.

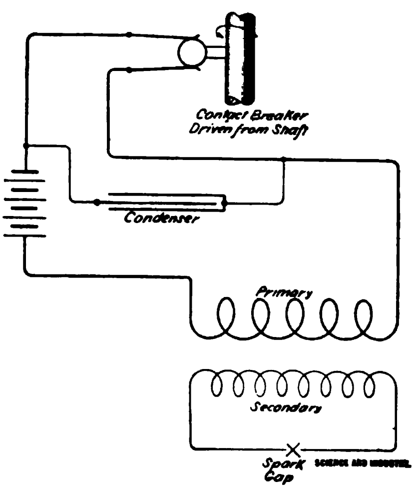
ANS.—To answer these questions fully, more space would be required than we have at our disposal. Only a mere outline can therefore be given. (*a*) The alternator is brought up to speed and its field excited, the main switch being open. The synchronizing lamps are then connected between the machines by inserting the synchronizing plug. As the machine comes nearly into synchronism, the fluctuations of the lamps will become slower, and when they have become as slow as one in two or three seconds the main switch should be closed at the middle of one of the beats. Whether the lamps will be light or dark at synchronism depends upon the character of the connections used in each particular case. After the two machines have been thrown together, the field excitation should be adjusted until the sum of the currents delivered by the two machines is a minimum for a given current delivered to the line. The load will divide between the machines in proportion to the power supplied to them from their prime movers and the division of load can therefore be varied by adjusting the governors. In order to shut down one machine so as to throw all the load on the other, gradually cut down the field excitation so as to reduce the load, then open the main switch. (*b*) If the machines are not in synchronism when they are thrown together, there will be an excessive rush of current between them. This is liable to produce severe mechanical strains in the machines, to say nothing of the electrical disturbance of the system. If the field excitation is not correct when the machines are in parallel there will be idle currents between the machines in addition to the current supplied to the line. In shutting down a machine the load should be removed as much as possible before opening the main switch in order to avoid breaking the heavy current and also to avoid any tendency towards racing. (*c*) You will have to obtain this from the makers of the alternators. The exciting current depends upon the characteristics of the machines and we are therefore unable to say just what it should be.

***

(226) (*a*) Can you give me a sketch of the proper way to connect an induction coil to give a jump spark for a gas engine, not using the vibrator? (*b*) Should there be a condenser in the circuit? (*c*) How large a condenser should be used on a coil that will give a ½-inch spark? (*d*) Which is more economical and reliable, a two-cycle or four-cycle gas engine?

I. H. W., Stony Ford, N. Y.

ANS.—(*a*) The accompanying figure shows the connections. The contact-breaking cam should be arranged so as to give a sharp,



quick break. If the break is slow, the coil will not give a good spark. (*b*) Yes. (*c*) About 20 sheets of tin foil 2½″ × 5″. (*d*) Taking all things into consideration, engines of the four-cycle type seem to have given the most general satisfaction.

MISCELLANEOUS

(227) (*a*) A simple 3° curve $A\ B\ C$, as shown in the accompanying sketch (Fig. 1), when located on the ground is found to

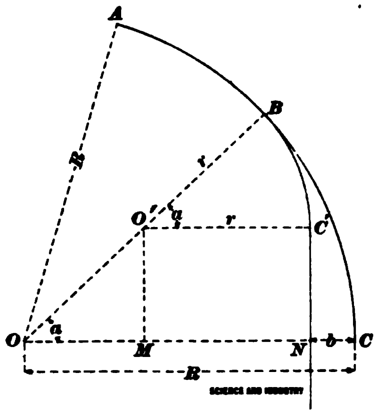


Fig. 1

strike a certain distance b outside of the original *P. T.*, which is at N. Required the radius of the curve $B\ C'$ that the original curve must be compounded into in order to close on the original *P. T.*, and the point of compound curvature B. Also, the same information when the end of the curve falls inside of the *P. T.* (*b*) A body is projected vertically with unknown velocity. The instant it leaves the earth is recorded, also the instant it returns. The interval is, say, 38 seconds. Required the initial velocity of the body in feet per second, the height to which it rises, and the time it is at rest before it returns to the earth. (*c*) Prove by geometry that the square described on the hypotenuse of any right-angled triangle is equal to the sum of the squares described on the other two sides. C. T., Belleville, Ill.

Ans.—(*a*) The radius R of the original curve being known, the point B, which is the *P. C.*, may be given or assumed, which will determine the angle a, or the angle a may be assumed, which will fix the point B. Or, the radius r of the second or modified curve may be given or assumed. If r is assumed, then, from a mere inspection of the figure, we can at once write the equation $O\,M + M\,N + N\,C = O\,C$, which can also be expressed in the form $(R - r)\cos a + r + b = R$ from which $\cos a = 1 - \frac{b}{R - r}$. If a is assumed, to find the value of r we have from the same equation $r = R - \frac{b}{1 - \cos a}$. The length of the tangent is increased by the amount $N\,C' = (R - r)\sin a$. When the end of the curve falls outside of the tangent, so that r is greater than R, the formulas become $r = R + \frac{b}{1 - \cos a}$, and $\cos a = 1 - \frac{b}{r - R}$. (*b*) Assuming that the body encounters no resistance except the force of gravty, the velocity can be calculated by the formula $v = g\,t$, in which v is the initial velocity in feet per second, g is the acceleration of gravity equal to about 32.16 in this latitude. In the present case, t is one-half the total time, equal to $\frac{38}{2} = 19$ seconds; hence, $v = 32.16 \times 19 = 611.04$ feet per second. The height to which the body rises is calculated by the formula $h = \frac{v^2}{2\,g}$; hence, $h = \frac{611.04^2}{2 \times 32.16} = 5{,}804.88$ feet. There is no interval of rest before the body returns to the earth. The instant the velocity becomes zero, the body starts to fall and continues with a constantly increasing velocity. (*c*) In Fig. 2, assume that $A\,C\,B$ is a right-angled triangle, and that $A\,B\,H\,K$, $A\,C\,F\,G$, and $B\,C\,D\,E$ are the squares described on its sides. Then is $A\,B\,H\,K$ equal to the sum of $A\,C\,F\,G$ and $B\,C\,D\,E$. For, draw the line $C\,P\,L$ perpendicular to $A\,B$ and $K\,H$; and draw the lines $C\,K$, $C\,H$, $B\,G$, and $A\,E$. The triangles $C\,A\,K$ and $G\,A\,B$ are equal, since $A\,K = A\,B$, $A\,C = A\,G$, and the angle $G\,A\,B$

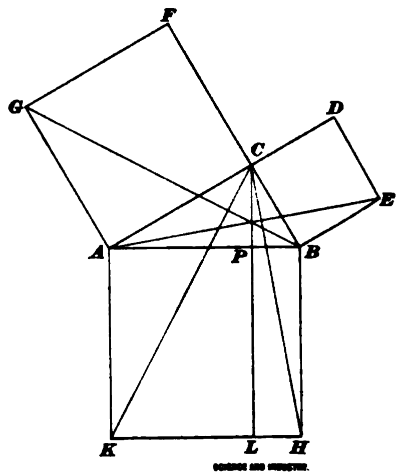


Fig. 2

is equal to $C\,A\,K$, since each is equal to 90° + $C\,A\,B$. The triangle $C\,A\,K$ and the rectangle $A\,P\,L\,K$ have the same base $A\,K$ and the same altitude $K\,L$, hence, $C\,A\,K$ is equivalent to one-half $A\,P\,L\,K$. In the

same way it can be proved that GAB is equivalent to one-half the square $ACFG$, and since CAK is equal to GAB, CAK is equivalent to one-half the square $ACFG$; therefore, $ACFG$ is equivalent to the rectangle $APLK$. In the same way it can be proved that the square $BCDE$ is equivalent to the rectangle $BPLH$. Therefore, the square $ABHK$, which is equal to the sum of the rectangles $APLK$ and $BPLH$ is equivalent to the sum of the squares $ACFG$ and $BCDE$.

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(228) (*a*) In answer No. 24, Vol. V, how did you know the diameter of the column? (*b*) *A* speaks the truth 3 times in 4; *B* 4 times in 5; and *C* 6 times in 7; find the probability that an event really took place which *A* and *B* assert to have happened and which *C* denies; the event being, independently of this evidence, as likely to have happened as not. How is the answer $\frac{140}{143}$ obtained? (*c*) Five men undertake to carry a stick of timber 30 feet long and of equal density and size throughout; one of the men takes a position at one end, and the others with a cross-bar place themselves so far from the other end that all shall carry an equal weight. How far from the end that the single man supports alone is

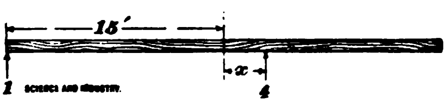

FIG. 1

the cross-bar placed? (*d*) A uniform lever 10 feet long balances at a point 1 foot from the end when loaded at that end with 50 pounds. Find the weight of the lever.

W. D., Hudson, Mass.

ANS.—The diameter of the column is assumed in the problem that is solved. The *d* in the formula given in this answer is equal to the sum of the diameter of the column and the diameter of the pipe, and the formula can be applied to any case of a winding pipe. (*b*) From the conditions of the problem, it is 3 to 1 that *A* speaks the truth, or the probability is $\frac{3}{4}$; 4 to 1 that *B* speaks the truth, or the probability is $\frac{4}{5}$; 6 to 1 that *C* speaks the truth, or the probability is $\frac{6}{7}$. When *C* denies a statement, it is 1 to 6 that it is true, or the probability of *C* being mistaken is $\frac{1}{7}$. Hence, the probability that the event happened is found by compounding the probabilities $\frac{3}{4}$, $\frac{4}{5}$, and $\frac{1}{7}$. Thus,

$$\frac{\frac{3}{4}\times\frac{4}{5}\times\frac{1}{7}}{\frac{3}{4}\times\frac{4}{5}\times\frac{1}{7}+(1-\frac{3}{4})(1-\frac{4}{5})(1-\frac{1}{7})}=\frac{2}{3}\text{ Ans.}$$

The answer that you give is wrong. The same result as is here given can be found by first finding the odds in favor of the event having happened. Thus, compounding the ratios 3 : 1; 4 : 1; and 1 : 6 gives 2 : 1. Hence, it is 2 to 1 that the event happened, or the probability is $\frac{2}{3}$. (*c*) The center of gravity of the stick of timber is 15 feet from each end. The weight carried on the cross-bar is to be

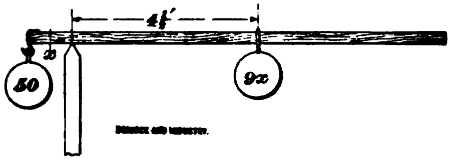

FIG. 2

4 times the weight carried at the end. Let the cross-bar be put at a distance x from the center of gravity of the stick. Then the forces acting are 1 and 4 (see Fig. 1), and the lengths of the arms of the forces are 15 and x. Therefore, $15\times 1 = 4x$, or $x = 3\frac{3}{4}$. Hence, the cross-bar should be placed $3\frac{3}{4}$ feet from the center of gravity, or $18\frac{3}{4}$ feet from the end, that the one man carries. (*d*) Let x = weight of 1 foot of lever. Then $9x$ = weight of long arm of lever. The $9x$ weight may be considered as centered at a point $4\frac{1}{2}$ feet from the point of balance on a lever without weight; the 1 x weight of lever at $\frac{1}{2}$ foot from point of balance (see Fig. 2). Then the moment $9x\times 4\frac{1}{2}$ is to balance the sum of the moments 50×1 and $x\times\frac{1}{2}$. That is, $9x\times 4\frac{1}{2} = 50+\frac{x}{2}$. Whence, $x = 1\frac{1}{4}$. Hence, the lever weighs $10\times 1\frac{1}{4}$ or 12.5 pounds. Ans. Again, 1 foot of the long arm may be considered as balancing the 1 foot of the short arm (see

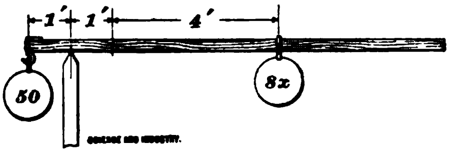

FIG. 3

Fig. 3), and 8 feet of the lever is to balance the 50-pound weight. Then the $8x$ weight is 5 feet from the fulcrum and its moment is $8x\times 5$, or $40x$. Hence, $40x = 50$; and $x = 1\frac{1}{4}$.

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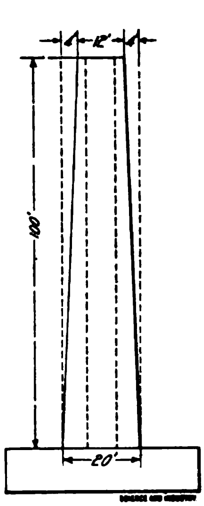
(229) (*a*) Show by graphical method how to determine the stability of the brick tower as per the enclosed sketch, figuring a wind pressure of 50 pounds per square foot on a flat surface. (*b*) Would the same method be employed for a hexagonal steel tower as per the sketch, and what would be the difference if same were open or enclosed with plates as per plan? (*c*) Is there any work treating of bracing and stability of towers and narrow-framed structures?

X. Y. Z., Milwaukee, Wis.

ANS.—(*a*) No graphical method can be employed for determining the stability of such a structure. It can, however, be readily calculated. The stability, or power to withstand the overturning force of the high winds, requires a proportionate relation between the weight, height, breadth of base, and exposed area of the tower. This relation is expressed by the formula $W = p\,\frac{b\,H^2}{d}$; in which W equals the necessary weight required in the walls of the tower, d equals the average outside diameter of the tower in feet, H equals its height in feet, b the breadth or diameter of the base in feet, while p equals the coefficient of the wind pressure in pounds per square foot of area. This coefficient varies with the cross-section of the tower, and equals 50 for a square, approximately 31 for an octagon, and 25 for a round tower. Thus, a round tower of the dimensions shown in the figure would require weight in walls, etc. of



$$\frac{25 \times 16 \times 10{,}000}{20},$$

or 200,000, to withstand a wind pressure of 50 pounds per square foot of flat surface; brickwork weighs about 120 pounds per cubic foot, consequently the average thickness of the walls of the tower should be about 12 inches if a factor of safety of $2\frac{1}{2}$ is desired, and the tower would be best designed with a wall 18 inches in thickness at the base, tapering to 8 inches in thickness at the top of the structure; this latter should be the minimum thickness for the top walls of any brick structure, such as a tower or stack. (*b*) The same method would apply to a hexagonal steel tower in order to determine its resistance to overturning about the base, but the determination of the stresses throughout the several members of such a structure becomes quite complicated. The resultant wind pressure on such a tower is greatly increased by enclosing it with plates. (*c*) We would advise consulting the work entitled "The Theory and Practice in the Design of Modern Framed Structures," by Johnson, Bryan, and Turneau, which may be obtained from any library, or purchased from the Technical Supply Co., of Scranton, Pa., for $10.

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(230) (*a*) Is there any chemical that can be used to prevent soot from falling down a chimney, sifting through the floor, and discoloring the plastering? (*b*) Having a building to design which is used as the grinding room of a paper mill, and is to be 53 × 33 feet, I would like to know how to proportion the foundations. The soil is clay, with little gravel and considerable water. (*c*) What should be the thickness of the walls for this building, which is 40 feet high, and is it necessary to tie these walls together? (*d*) How should the engine bed be constructed to insure the greatest rigidity? "MACBETH," Fredericton.

ANS.—(*a*) We know of nothing that will prevent the gathering of soot in a chimney, though it is not so likely to collect when the inside of the chimney is pargetted—that is, plastered smooth. (*b*) A good soft clay, though it is wet, will carry from 2 to 3 tons per square foot, without excessive settlement. We would advise that you use concrete footings. These footings should be 6 inches wider than the wall on each side, or about 28 inches in width, and the concrete should be laid 12 inches in thickness. It may be necessary in excavating to sheet pile the ditch in which the concrete is to be tamped. The presence of water in the ditch makes no difference if a good quality of Portland cement is used in mixing the concrete. We would advise, if there is considerable water in the foundations, and the brickwork is carried to the concrete footings, that you put a damp-proof course in the brick walls about 1 foot above the ground. This can be either a layer of slate, some good impervious stone, or a mortar joint of asphaltum around the entire building. (*c*) The wall, half way up, should be 16 inches thick; for the remainder it should be 12. It would be advisable to reenforce the walls with pilasters at intervals of about 10 to 14 feet, the pilasters having a 24-inch face and an 8-inch projection in the first story, and a 24-inch face and 12-inch projection in the second story. In other words, the face of the pilaster is carried up on the same plane throughout the height, and the wall offset 4 inches in the upper half. The off-set can occur either on the inside of the wall or the outside. When the offset is made outside, with the window openings and pilasters, a pleasing architectural treatment can be obtained, a stone-sill course being provided at the offset. It is not necessary if the walls are proportioned in this way for the size of the building which you mention, to tie them together. The roof trusses can be anchored to the tops of the walls, and will add somewhat to their stability. (*d*) The engine foundations, which we presume, include fouudations for the hogs, or grinding machines, should be carried down to the bottom of the footings of the building. The foundations can be either constructed of brick or, better still, of concrete.

SCIENCE AND INDUSTRY

Vol. VII September, 1902 No. 9

TWO METHODS OF SETTING DUPLEX PUMP VALVES

THE ordinary direct-acting duplex steam pump requires anywhere from 100 to 200 pounds of steam per horsepower hour when working to the best advantage—that is, when everything is in good working order. It is important, therefore, that the valves be properly set so as to secure a full stroke on both sides, and a uniform speed of the pistons.

The method of setting valves is of no value in itself, because it is the results obtained on which the success or failure in operation depends. There are two methods of setting the valves of duplex pumps, both of which give good results when properly used; in fact, the results are identical so far as the time required and the operation of the pump, when the work is finished, are concerned. One method necessitates taking measurements and making certain adjustments in accordance therewith, while with the other method the extent of the adjustments is always in plain sight and to some persons this tends to simplify matters. While both methods are good, some prefer one and some the other, so we present them both, that the one appearing the more simple may be chosen.

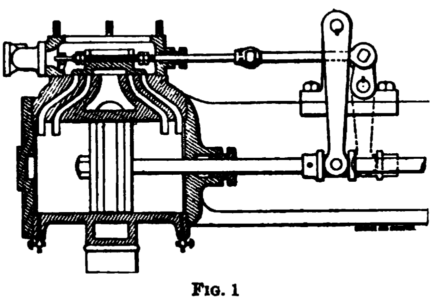


FIG. 1

In both methods the steam-chest cover is first removed and the glands in the stuffingboxes of the piston and valve rods slackened considerably, so as to permit the rods to move freely through the packing. In the first method the rocker-arms, or levers, employed to actuate the valves are brought into a vertical position and placed exactly plumb, as shown in Fig. 1. It is not necessary to use the plumb-line and bob when doing this, because any person with a good "eye" can tell by simply looking at the levers whether they are plumb or not, or at least sufficiently so for the purpose of setting the valves. It is possible by the careful manipulation of the throttle to stop the pump with the valve gear nearly in the proper position, and when this can be done the time required to set the valves is oftentimes considerably reduced.

When the levers, or rocker-arms, are plumb, they occupy the position known as mid-stroke, and, were it not for the play necessary between the valve and the locknuts on the valve stem, the valves would occupy the corresponding position known as mid-travel. Pump valves, unlike engine valves, have no

lap, so that when they are placed at mid-travel the ends of the valves should just cover the steam ports, the edges of the valves and the outer edges of the steam ports being then in line.

When the valves are properly set, should the rocker-arms be stopped in the position shown in Fig. 1, the valves would occupy the position illustrated in Fig. 2. One steam port leading to each cylinder is partly open, one piston having been moved in one direction and the other in the opposite direction. The lost motion, or play, between the valves and the locknuts on the stems, renders it impossible to stop a duplex

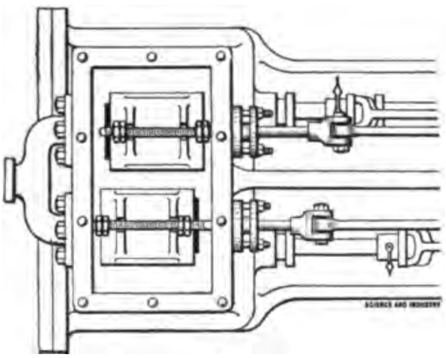


FIG. 2

pump in any position from which it cannot be started by simply admitting steam, when the valves are properly set; in other words, the pump has no dead center. When one piston moves to the end of the stroke, it pulls or pushes the opposite valve to the end of its travel; then, owing to the lost motion between the valve and the nuts on the stem, when the piston starts back to the other end of the stroke the valve remains stationary until the piston has completed about one-half stroke. During this time the opposite piston has completed a full stroke and the valve operated by it will have opened the steam port wide, so that, while one valve covers both steam ports, the other is at the end of its travel. The object in view when setting the valves of this style of pump is to secure these conditions of operation.

After placing the rocker-arms plumb, measure the width of the steam port and then set the valves squarely over the ports, so that both steam ports on both sides of the pump will be just closed. The space between the nuts and the lugs on the backs of the valves should be equal to one-half the width of the steam port—that is, if the valves were now to be moved in either direction, the steam ports would be one-half open.

If the nuts are not in the proper position, they must be loosened and adjusted so as to leave the proper spaces at each end of the valve.

Difficulty is frequently experienced when attempting to lock the nuts on the stem after they have been loosened. If the nuts fit the stem loosely this will nearly always occur, and in this case two wrenches should be provided, one to hold the nut nearest the valve while the other is being tightened. If only one wrench is used, the inside nut is liable to be moved while tightening the outer one, thus necessitating going over the work again.

As the valves will now be in a position to entirely prevent the admission of steam to the cylinders, it will be necessary to move at least one of them so as to open one of the ports. The chest cover may now be put on and the stuffingbox glands tightened sufficiently to prevent leakage. If upon starting the pump one piston should move slowly when approaching the end of the stroke, or perhaps fail to complete the stroke, the pump should be stopped after the piston has moved as far as it will go and the chest cover removed. It will generally be found that the port admitting steam is not wide open,

which may be due to one of the nuts having been moved farther than was necessary. If the port is found to be wide open, the difficulty will be found in the cylinders or the stuffingboxes on the piston rods. These, of course, should receive attention so that the pump may be able to work to the very best advantage.

In the second method of setting pump valves the pump is stopped with the pistons at the end of the stroke. If this position cannot be obtained with the throttle, then the proper position of the pistons should be marked on the rods at both ends of the stroke so that the correct position may be secured after the steam is turned off. Assuming that the steam-chest cover has been removed, the valves will be found in the position indicated in Fig. 4 (provided they are properly set). If the steam distribution has been bad, the valves will either not open the ports wide, as shown in Fig. 3, or they will have opened them too wide, depending on which end the difficulty occurs. To set the valve, see that one piston is at the end of the stroke, as shown in Fig. 3, in which view the valve has considerable "under travel," that is, it does not make a full stroke and therefore cannot open the port wide as it should. The nuts on the stem must now be screwed up, pushing the valve along until it opens the port wide. Lock the nuts in this position, and then push the piston to the other end of the stroke and see that the opposite steam port is opened wide, as shown in Fig. 4. If it is not thus opened, it indicates that the upper rocker-arms are not long enough to give the valve full travel. In this case the nuts not in contact with the valve should be set up, or moved toward the valve, an amount equal to one-half the difference between the port opening, as observed at both ends of the valve, and the other nuts backed off a like amount. The valve will then open both ports the same amount when the piston

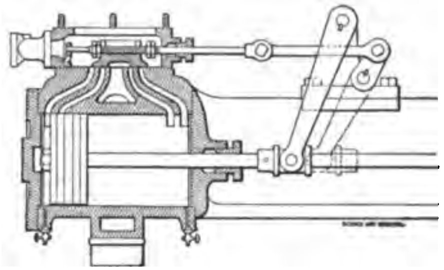


FIG. 3

reaches the ends of the stroke. The opposite side of the pump is adjusted in a similar manner.

It will be noticed that with this method the port is opened wide, instead of closed, when the valves are properly set, consequently, when setting them the valves must be moved by means of the jamb nuts until this condition exists, which is easily done because both the edges of the port and the end of the valve are in plain sight during the whole operation.

The latter method has its drawbacks, however, because the pistons have to be moved from one end of the cylinder to the other in order to equalize the travel of the valve, except where it is known

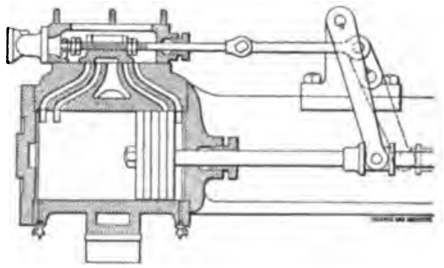


FIG. 4

that the valve will open both ports wide when the pistons reach the ends of the stroke. It will no doubt be seen that the former method is

preferable when setting the valves of large pumps, where it is generally inconvenient to move the pistons back and forth by hand, while the latter

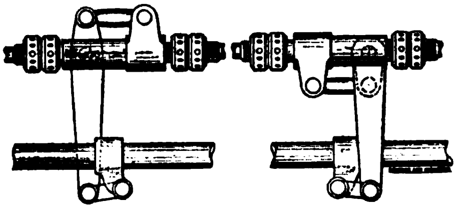


FIG. 5

method will best meet the needs of persons who prefer to have the limits of adjustment always in plain sight, thus obviating the necessity of measurements.

Certain makes of pumps employ the style of adjustment illustrated in Fig. 5, especially on the larger sizes. In this gear the adjusting nuts are outside of the chest and are loosened and tightened by inserting a steel pin in the small holes in the periphery of the nuts. The valve is set in exactly the same manner with the outside nuts as with the inside nuts, those on the outside being adjusted with reference to the sleeve the same as the inside nuts are with reference to the lugs on the backs of the valves.

Another style of gear with outside adjustment is shown in Fig. 6. In this construction the position of the valve relative to the rocker-arm is adjusted by means of the screw-threaded ends of the link and the sleeve nut, as shown. One advantage possessed by the two latter styles of adjustment is that the valve may be set without removing the steam-chest cover. This is accomplished by making a gauge of the form shown in Fig. 6 long enough to reach from some fixed point on the chest to a point on the valve stem. When the valve is placed squarely over the ports, place the gauge against the chest and make a mark on the valve stem corresponding with the point of the gauge. Then move the piston (and valve) to the ends of the stroke and make a similar mark, which should be made when the ports are wide open. The stem is generally not adjustable at the valve when this style of gear is employed, so that when again setting the valves the latter may be placed centrally over the ports by means of the gauge, all that is necessary being simply to bring the central mark on the stem under the point of the gauge.

When the second method is employed, the lines representing the port wide open should be used.

In the steam engine only three port are used, two for admitting live steam and one central port for conducting the exhaust steam to the exhaust pipe.

In steam pumps five ports are employed, two for admitting steam only, two for exhausting steam only, and the fifth, or central, port the same as in the engine. It is necessary to cushion the piston in direct-acting pumps, so that when high speeds are reached the pistons at one end, and the plungers at the opposite end, will not strike the cylinder heads. The cushioning effect is secured by providing a separate exhaust port so located that when the piston has nearly completed the stroke

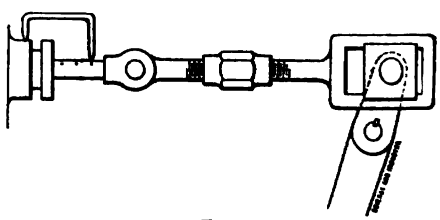


FIG. 6

it will close the exhaust port and entrap a portion of the exhaust steam. This steam is confined between the piston and the cylinder head, and being

prevented from escaping through the steam port, by the valve, it is compressed and thus stops the piston before it reaches the cylinder head.

In fire-pumps, which frequently run at high speeds in case of fire and at very low speeds at other times, what is called a cushion valve is put in just above the bore of the cylinder. This valve is placed in a short port connecting the steam and exhaust ports leading from the main valve to the cylinder, as shown in Fig. 7. The object of the cushion valves is to regulate the stroke of the pistons so that a uniform length of stroke may be obtained regardless of the speed of the pump. By referring to Fig. 3 it will be seen that, when the cushion valve is closed, all the steam between the piston and the cylinder head will be compressed and the stroke will be considerably shortened. When this valve is partly open, as in Fig. 7, a portion of the steam may flow through the by-pass from the steam port into the exhaust port and thus tend to lessen the pressure of the compressed steam, and therefore permit the piston to travel nearer the cylinder head, thus increasing the length of the stroke. When a pump runs very slowly, it is oftentimes necessary to open the cushion valves wide in order to obtain a full stroke. When pumps are provided with these valves, the speed should be increased gradually and the cushion valves slowly closed as the speed increases.

On the frame of most pumps are two marks on each side, which represent the

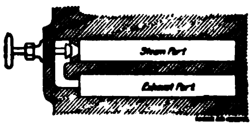


FIG. 7

extreme length of stroke, and the cushion valves should be so adjusted that the pointer attached to the piston rod will ordinarily stop at a point slightly within these marks. It is very important that fire-pumps should make a full stroke, especially when a fire occurs and the full capacity of the pump is needed, without danger of the pistons or plungers striking the cylinder heads.

HOW ELECTROMOTIVE FORCES MAY BE PRODUCED

A DIFFERENCE of electrical potential or an electromotive force may be produced or generated in a number of different ways, among which are the following:

(*a*) By friction and electrostatic induction, as in static machines.

(*b*) By moving a conductor across a magnetic field, as in a dynamo.

(*c*) By dipping the ends of two strips of dissimilar materials into a liquid that has a greater tendency to chemically act upon one material than upon the other, as in a battery. The electromotive force is maintained by chemical action.

(*d*) By the contact of two dissimilar materials, especially where there are two junctions, at different temperatures. An electromotive force produced in this manner is called a thermo-electromotive force. A thermopile is a device in which thermo-electric currents are produced by a thermo-electromotive force due to a difference of temperatures between contacts of dissimilar substances, usually metals or alloys of metals. Thermopiles were once tested by a company using a large number of primary cells, with the intention of substituting them for primary cells for certain purposes, but their efficiency was too low.

USEFUL FORMULAS—VIII

JOSEPH E. LEWIS, S. B.

FALLING BODIES $v = \sqrt{2gh}$

IT is our purpose in this article to discuss briefly the motion of bodies in space and the laws by which moving bodies are governed. In selecting the case of a falling body for special mention it is not the writer's purpose to limit our consideration to this form of motion alone, but rather to use it as a typical case and one capable of many modifications in actual practice. It is also a somewhat difficult form of motion to explain in a clear manner, and before trying to analyze it we shall do well to consider some of the simpler principles involved.

When bodies are moving there is always a relation which may be determined between the distance traveled, the time occupied in the journey, and the velocity or rate of speed at which the body moves. A railroad train, for example, travels a certain distance in a given time; we can readily compute the speed by dividing the space s by the time t. That is, if v stands for the velocity, we have $v = \frac{s}{t}$ or $s = v\,t$. This is called *uniform* motion, and is the simplest to understand. In general we may say that there are two kinds of motion, *uniform* and *variable;* of variable motion we shall speak more at length presently.

Uniform motion occurs unde two different conditions; namely, when a body moves freely in the absence of all accelerating or retarding forces, or, as is commonly the case, when the retarding and accelerating forces just balance. The first case is the ideal one. This case would be realized if it were possible to find a body somewhere in space, so far from every other body in the universe as not to be attracted in the least degree one way or the other. Such a body if in motion would move freely and uniformly in a straight line, without changing either its velocity or its direction, and we should have the ideal case of uniform motion which would be nothing more nor less than "perpetual motion."

The second case of uniform motion is the one with which we are familiar, both in nature and in mechanics. And here, too, we shall find that most abused of all phenomena, "perpetual motion." It is very true that "perpetual motion" is popularly supposed not to be a possibility, despite the fact that some crank or other makes the announcement every little while that he has discovered it. If by "perpetual motion" we mean uniform, established motion, it is the most common phenomenon in nature. The earth moves continually in its orbit around the sun, and at the same time whirls round upon its axis. The whole universe of worlds is one great illustration of perpetual motion. Here are bodies which move forever in their appointed orbits. It requires no engine to drive them. The explanation is simple; there is nothing to stop them. Friction, that great absorber of energy, is entirely lacking; and the forces of attraction and repulsion are so nicely balanced that the resultant effect upon the motion of the body is zero. Hence the motion is constant, perpetual, and so far as concerns us, uniform.

If, on the other hand, we mean by "perpetual motion" something which will do work without using up energy, that is, if we are trying to get something for nothing, our search will be

as vain and our efforts as fruitless as have been those of all others since men first began to search for the "philosopher's stone." The heavenly bodies move perpetually but they do no work, and therefore it requires no energy to maintain their motion.

In mechanics it is different. Here we encounter friction which brings our machinery to a stop sooner or later, if the supply of energy be removed, however delicate the mechanism or true the balance and adjustment. We have uniform motion, however, when the energy supplied just equals and balances the work being done, as, for instance, when one engine runs at constant speed supplying power to the mill, or when a train of cars or a steamboat is moving at a uniform speed.

What has already been said should prepare the way for a statement of the First Law of Motion, as expressed by Sir Isaac Newton more than two centuries ago. It is as follows: "Every body continues in its state of rest or of uniform motion in a straight line, except in so far as it may be compelled by force to change that state." The two centuries which have elapsed since he first gave this law have not shown a necessity for any change or modification. The fundamental principle which underlies this law is the principle of the *inertia* of matter. It states that matter of itself has no power to change its condition either of rest or of motion; and hence that when at rest it must continue at rest, or when in motion it must continue in motion, unless some external force intervenes to change its condition. Both motion and rest are equally normal conditions of matter.

Let us turn now to the question of variable motion. Motion may vary erratically when affected by changing or intermittent forces, or we may have *uniformly* variable motion when the forces acting are constant. If the sum of the forces compelling motion is greater than the sum of those tending to destroy it, we have a uniformly accelerated motion; if the reverse is the case, we have a uniformly retarded motion. To illustrate: If a stone be thrown into the air, its upward motion is uniformly retarded by the force of gravity, until it comes to rest, and then its downward motion is uniformly accelerated by the same force until it reaches the ground.

In general we may say that motion in which there is a constant acceleration or retardation is uniformly variable, being either uniformly accelerated or uniformly retarded. In such motion the velocity is constantly changing, either increasing or diminishing at a uniform rate, and the velocity at any particular instant is the space over which the body would move in a unit of time, were the accelerating or retarding force to cease its action.

Now, we found in the case of a uniformly moving body a very simple relation between the velocity, the time, and the space traversed, and we indicated these quantities by the letters v, t, and s, respectively, for the sake of brevity. We may also find a similar relation in the case of uniformly variable motion, but here the relation, although in a general way similar, is by no means so simple.

Take first the case of uniformly accelerated motion. Here the speed is constantly increasing, as when a stone falls from a height to the ground. The space traveled will be the height from which the stone falls, which we will call h, instead of s. Suppose it takes the stone several seconds to fall to the ground, then, at the end of each second, it is moving faster than at the end of the previous one; that is to say, its

velocity is increased by a certain amount every second as long as it continues to fall. This increment of velocity is actually equal to about 32.2 feet per second, and we will call this quantity g, for short. When the stone begins to fall, its velocity is zero at the start; at the end of the first second, it is moving at the rate of 32.2 feet per second; at the end of the next second its velocity is 64.4 feet per second; and at the end of the third second its velocity is 96.6 feet per second, and so on, increasing at the same rate as long as it continues to fall. It appears, then, that the velocity at the end of a given number of seconds will be found by multiplying the time by 32.2, or $v = g\,t$.

To find the value of h, or the distance that the stone falls in a given time, t, we may use this formula: $h = \frac{1}{2}\,g\,t^2$. That is to say, the distance fallen (in feet) is equal to one-half of 32.2 multiplied by the square of the time in seconds. It would take us somewhat beyond the scope of this article to demonstrate the truth of this statement, and we will therefore ask the reader to accept the formula as it stands. Any standard work on mechanics or physics will give the complete demonstration for those who wish to look it up more thoroughly.

We may now combine the two formulas given above and deduce a relation between the velocity and the height by getting rid of the time element. We have $v = g\,t$, whence $t = \frac{v}{g}$, and by squaring both sides, $t^2 = \frac{v^2}{g^2}$. From the other formula, $h = \frac{g\,t^2}{2}$, we have $t^2 = \frac{2\,h}{g}$. Now, since "things which are equal to the same thing are equal to each other," we have $\frac{v^2}{g^2} = \frac{2\,h}{g}$, or $v^2 = 2\;g\,h$, whence by taking the square root of both sides we obtain the formula, $v = \sqrt{2\;g\,h}$, which appears at the head of this article.

The case of uniformly retarded motion is quite similar. Here the body has an initial velocity, v_1, at the start, instead of zero as before. Each successive second this velocity is diminished by a certain amount. Take the case of a stone thrown into the air with a velocity of 96.6 feet per second. At the end of the first second the speed is $96.6 - 32.2 = 64.4$ feet per second, and at the end of the third second the body comes to rest and starts downward again. Then the velocity after going up for t seconds equals $v_1 - g\,t = v$. In the same way $h = v_1\,t - \frac{1}{2}\,g\,t^2$.

It is also true that the velocity of the stone when it strikes the ground is exactly what it was when it started upward, and furthermore, the velocity at any given height is the same either going up or coming down. Any one can demonstrate this to his own satisfaction by figuring the velocity from the formulas given above. The force with which we are dealing in the consideration of falling bodies is the force of gravity. This is not absolutely a constant force, but it is so to all practical purposes, so that we do not err measurably in considering it as such.

Another paradox, is the fact that the weight or size of a body does not make any difference in the velocity which it attains in falling, or in the time which it takes it to reach the ground. This statement would be absolutely true were it not for the resistance which the air offers to bulky objects. A feather would fall to the ground as quickly as a piece of lead if it were not for the resistance of the air, which acts strongly upon the one and almost not at all upon the other. This

may be proved by a simple experiment. In a long glass tube closed at both ends are placed a penny and a feather. Hold the tube vertical and they both fall to the lower end, the cent quickly, the feather slowly. Reverse the position of the tube and the same thing occurs again. Now produce a vacuum in the tube by means of an air pump, and when the air is practically all exhausted it will be found that the feather will drop to the end of the tube exactly as quickly as the penny.

One other curious fact which we may notice in closing, is that the distance which a body falls in the first second is just one-half of the velocity which it attains, or 16.1 feet. This will be seen from the formula, $h = \frac{1}{2} g t^2$. Let $t = 1$ and $h = \frac{1}{2}$ of 32.2 or 16.1.

ENCLOSED ARC LAMPS—II

IN THE last article we confined our attention to constant-potential enclosed arc lamps. In this article constant-current lamps will be considered. For street lighting or for any place where lights are scattered over a wide area, they are operated in series instead of in parallel, because the supply of energy to the lamps can be effected with a much less expenditure for line wire. In the series system the same current flows through all the lamps, and the voltage generated by the dynamo is equal to the voltage per lamp multiplied by the number of lamps. In the parallel system the total current supplied by the dynamo is equal to the current per lamp multiplied by the number of lamps, and the voltage is the same as that supplied to a single lamp. In other words, the series system uses a small current at high pressure, whereas the parallel system uses a large current at low pressure, and, hence, requires larger wires for the transmission of the current.

Series-enclosed lamps are operated by either direct or by alternating current. If direct current is used, it is supplied from a dynamo which is provided with an automatic regulator which causes the voltage generated to increase as lamps are switched on, and decrease as they are switched off, thus maintaining the current at a constant value regardless of the number of lamps in operation. When alternating current is used, it is generally supplied either from a special constant-current transformer or from a transformer in connection with a regulating device, such as an adjustable reactance coil which keeps the current at a constant value.

In the last article we saw that the regulation of a constant-potential lamp could be effected by a single coil in series with the arc, used in conjunction with a resistance coil or a choke coil. In the constant-current lamp, the regulation cannot be effected in this way because the current is automatically maintained at a constant value regardless of the length of the arc, and it is evident that a coil inserted in series would exert a constant pull and would be of no value for regulating purposes. Some other arrangement must, therefore, be used. Also, since the current is maintained at a constant value, there is no need of a resistance coil or reactance coil in a series lamp, at least not so far as the regulation is concerned. As will be seen later, resistances are sometimes used for another purpose.

With a constant current it is evident that the voltage necessary to maintain the arc between the carbon points will

increase as the length of the arc increases, and if a coil were connected across the carbons, the current in this coil would increase as the arc increases. A coil connected in shunt with the arc may, therefore, be used for effecting the regulation of a series lamp. The regulation may be effected by a shunt coil alone or by a shunt coil in conjunction with a series coil, as shown in Fig. 1. This diagram represents an elementary lamp, and is intended simply to illustrate the principle involved rather than to represent a lamp as actually constructed. *S* and *S′* are two solenoids; *S* is of comparatively

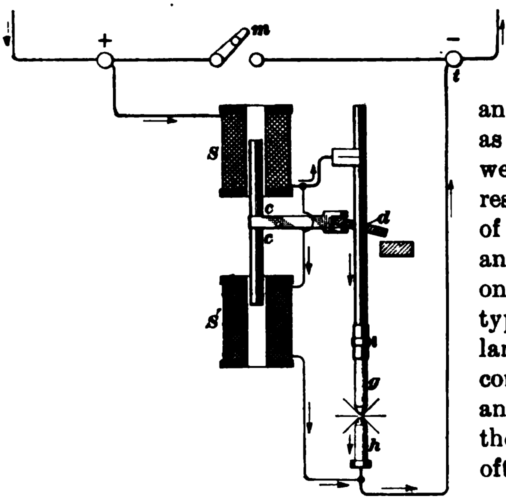


FIG. 1

coarse wire and is connected in series with the carbons. *S′* is of fine wire and is connected across the carbons so that a small portion of the current flows through it, as indicated by the arrows. The current in *S* is constant, and coil *S*, therefore, exerts a constant upward pull on the iron core *c c*. *S′* exerts a downward pull which increases as the carbons burn away, because, as the gap between *g* and *h* increases, more current takes the path through *S′*. A switch *m* is provided for short-circuiting the lamp when it is to be cut out of circuit. When the lamp is out, the carbons *g h* are in contact. When the lamp is thrown into circuit, the main current passes between *g* and *h*, but since the carbons are in contact there will be very little drop between them and very little current will pass through *S′*. Coil *S*, therefore, pulls up the core *c c* causing the clutch *d* to grip the carbon rod, and thus pull up the carbon and start the arc. The instant that the carbons separate, current flows through *S′* and the pull of *S′* is opposed to that of *S*. The core, therefore, takes up a position where the two pulls balance each other. As the carbons burn away, the pull exerted by *S′* increases, and the core is pulled down until the clutch *d* is released and the carbon allowed to feed. As soon as the carbon feeds, the pull of *S′* is weakened and equilibrium is again restored. From the fact that the pulls of *S* and *S′* are opposed to each other and that the feeding, therefore, depends on the difference in their pulls, this type of lamp is known as a differential lamp. In some lamps the feeding is controlled entirely by the shunt coil, and a series coil is used only to start the lamp. Lamps of this kind are often referred to as shunt lamps.

Series-enclosed lamps are, like the constant-potential lamps, made in great variety. Some of them are of the differential type, others of the shunt type, and both kinds are made for direct and alternating current. Fig. 2 shows the essential parts of a series-enclosed lamp of well-known make. This lamp is for direct current, and belongs to the differential class. There are two shunt coils and two series coils mounted in the upper part, as shown at *S* and *M*. Only one coil of each pair appears in the figure, the others being directly behind those shown. A tube *T* holds

the upper and lower parts of the lamp together, and in it the carbon holder *H* carrying the upper carbon *U* is free to slide up and down. Current is carried to *U* by means of an asbestos covered cable *C*. The magnets *M* and *S* attract the armatures *d* and *e*, which are hinged together by the levers *a b* so that when one armature rises, the other falls. When the series magnet *M* pulls up armature *d*, the clutch *g k* grips the top carbon and raises it. As the arc lengthens, armature *e* is pulled up, thus lowering clutch *k* until it finally rests on the tripping table *l*, when any further movement releases the clutch and allows the lamp to feed.

In series lamps it is necessary to provide a cut-out or automatic device that will preserve the continuity of the circuit around the lamp in case the carbons should fail to feed properly. In Fig. 2 the cut-out consists of contact pieces *2*, *2'* that are connected together by the cross-piece *n* when the armature *e'* is pulled up to its farthest position by the shunt coils *S*.

The connections of the lamp are shown diagrammatically in Fig. 3. *M*, *M* are the series coils and *S*, *S* the shunt coils as before. The adjustable resistance *r* is in shunt with the series coils, and by varying this resistance the amount of current passing through them can be varied to suit the conditions under which the lamp is operated. The shunt coils *S*, *S* are connected directly across the carbons, and, hence, the current in them will increase with the length of the arc. The cut-out contacts *2*, *2'* are connected as shown, and when these contacts are bridged by *n* there is a direct path from *T*+ to *T*— through the resistance *P*.

When the lamp is operating under normal conditions, the main current enters at *T*+, flows through the series coils *M*, *M*, across the carbons, thus forming the arc, and out at *T*—. A small portion flows through the shunt coils, and by means of the joint action of the series and shunt coils the lamp is regulated as previously explained. In case the carbons should stick or fail to feed, or if a carbon should become broken, a strong current flows through the shunt coils, thus pulling up armature *e*, Fig. 2, to its extreme position

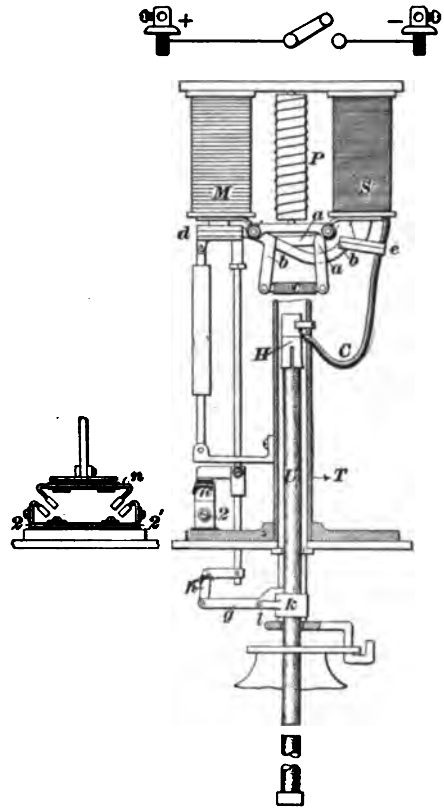


FIG. 2

and bringing *n* in contact with *2*, *2'*, Fig. 3. The current then takes the path *T*+ -*P*-*2*-*n*-*2'*-*T*— and passes on to the other lamps. If the cut-out were not provided, all the other lamps on the circuit would be put out.

The resistance *P*, Fig. 3, is known as the starting resistance and is inserted in series with the cut-out to

enable the lamp to start up in case the carbons should feed down so as to allow the current to pass. If *P* were not in series with the cut-out, it is evident that the resistance from $T+$ to $T-$ by way of the cut-out would be extremely low, and even if the carbons should feed down properly enough current would not pass through *M*, *M* and the carbons to start the lamp. If, however, a resistance *P* is inserted, there will be an appreciable potential across the series coils and sufficient current will pass through them to start up the lamp.

In Fig. 3, two coils *S'*, *S'* in shunt with *M*, *M* will be noticed. These coils are wound under the shunt coils *S*, *S* and, therefore, exert a pull opposed to the coils *M*, *M*. The object of these coils is to compensate for the variation in the pull of the shunt coils due to their heating. The shunt coils have a considerably higher resistance after the lamp has been running an hour or two than when it is first started. Now the voltage across the shunt coils is equal to the voltage across the arc, and if the arc is to be maintained at a constant length, some means must be provided for keeping the pull exerted by the shunt coils uniform. A number of different schemes have been used to accomplish this end. One method is to shunt the series coils by means of a resistance having a low temperature coefficient, i. e., a resistance that increases but very little with an increase in temperature. When the coils become heated, the pull of the shunt coil decreases, but the pull of the series coils also decreases because they become heated and, being of copper, increase considerably in resistance so that a larger proportion of the current passes through the shunt resistance. In Fig. 3, therefore, the pull of *S'*, *S'* becomes greater as the lamp heats up, thereby compensating for the decreased pull of *S*, *S*. Series-enclosed lamps, like the constant-potential lamps, are made in great variety, and the above example has been taken simply to illustrate some of the more important points in connection with them. Many of the lamps would, of course, differ from this particular example in details of construction and also in connections. The mechanism of series-enclosed lamps is, as a rule, quite simple, though the presence of the cut-out makes them somewhat more complicated than constant-potential lamps. The fact that these lamps operate on constant current necessitates the use of a shunt magnet to affect their regulation.

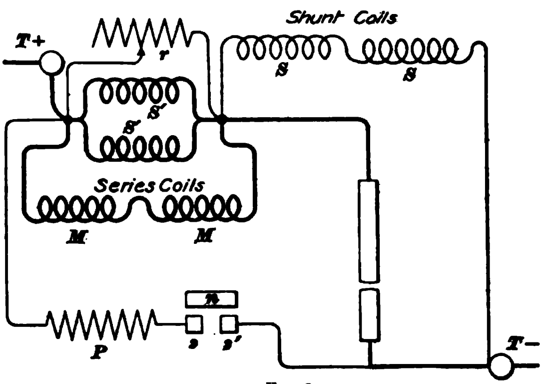


FIG. 3

SOME POINTS ON THE RUNNING AND MANAGEMENT OF BELTS—III

IT HAS already been pointed out that the velocity and horsepower of belting, like many other elements, are very much a matter of choice and judgment. There are those who contend that the higher the speed the better, both for the leather and with reference to the first cost, while others put a limit upon the speed, which ranges from 3,500 to 5,500 feet per minute, depending upon the circumstances. There is evidently no fixed speed limit in connection with belting, any more than there is in connection with steam engines. One engineer may consider 300 revolutions per minute the safe or economical limit of speed for an engine while another will place it at 500 under the same conditions. Under ordinarily good conditions of temperature and load to be found in factory service, where the belts run close to the ceiling, from 3,000 to 3,500 feet per minute is about the limit when considering the general effect on the belt. A belt traveling at the rate of 3,500 feet per minute will be found to dry out and become hard and stiff in a very short time, and in a still shorter time as the speed increases. This necessitates very careful watching and considerable time being spent upon it in order to keep the belt soft and pliable and in a condition to transmit the maximum horsepower without slipping, that is, when the initial tension and friction are reduced to a minimum. The apparent gain due to the higher speed will be offset by the additional labor required to keep the belt in a condition favorable to the best results. A belt traveling 3,500 feet per minute will require a tension of but $9\frac{1}{2}$ pounds for each inch in width in order to transmit 1 horsepower, and one having a width of $100 \div 9.5 = 10.5$ inches will transmit 100 horsepower.

It will be observed that this approaches very closely the maximum speed practicable for belting for factory service, when the efficiency and the life of the belt are considered.

One is very apt to conclude, and many do, that the speed, tension, etc. given in the rules and formulas on belting indicate the manner in which a belt should be run, if it is expected to run at all, and numerous instances can be cited where belt drives are of ridiculous proportions, the result of attempting to put into practice the proportions derived from calculations alone. While accurate formulas pertaining to all branches of engineering are invaluable in the hands of experienced mechanics, they do not indicate, in all cases, what must be done in order to obtain satisfactory results, but they do indicate what a certain belt, for instance, may be expected to do, and what it can do under the conditions upon which the formulas are based. Formulas indicate the limit or the maximum quantity, as a rule, that may reasonably be expected. It is very evident that we do not always have to realize the maximum in any particular, in order to obtain satisfactory results. When a writer uses 1,600, 1,800 or 2,000 feet per minute in calculations, it is not to be inferred that a belt must necessarily be run at this speed in order to give satisfaction in more ways than one, but this figure does indicate that 1,600, 1,800 or 2,000 feet per minute or any other speed that may be given is, in his opinion, the maximum or minimum, as the case may be, under which the best results may be realized; that is, at this speed,

or tension, the belt will transmit the greatest number of horsepower with the least loss and with the lowest cost of maintenance and at the same time

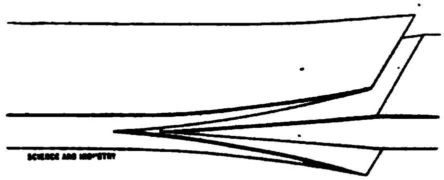


FIG. 1

prove favorable to the life of the belt. When these requirements are satisfied the highest efficiency will be realized. When any of the quantities considered are changed, the efficiency of the belt, all things considered, will be lessened —it may become more efficient in one respect, but it will be found less efficient in another. But this is saying nothing concerning satisfactory results. Take a belt used for driving a grindstone. It will "pull" the stone under the heaviest pressure brought to bear upon it in ordinary work; it will run it at the proper speed; the belt is heavy enough to give it good wearing qualities and wide enough and tight enough not to slip when water is accidentally splashed on it or on to the pulley. The belt gives perfect satisfaction, but it is not running under those conditions which must exist in order to secure maximum efficiency. If we were to attempt to run this belt under the conditions required for the highest obtain-

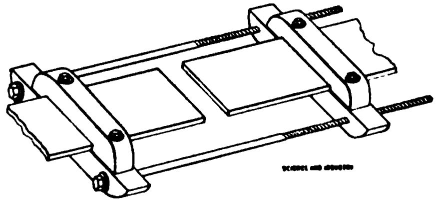


FIG. 2

able efficiency it would be wise to make use of a more expensive drive and of one or more of the formulas already given, otherwise we would be apt to either overdo the thing, or fall short of what might have been accomplished.

The horsepower a belt in good condition may be expected to transmit, may be estimated by means of the following formula: $\frac{W D R}{2,100} = \text{H. P.}$ for a double belt, and $\frac{W D R}{2,800} = \text{H. P.}$ for a single belt, in which W represents the width of the belt, D the diameter of the pulley, both in inches, and R the number of revolutions per minute. To illustrate the application of the formula, assume a double belt 20 inches wide running on a pulley or pulleys 60 inches in diameter making 160 revolutions per minute. In this case $W = 20$, $D = 60$, and $R = 160$, and the horsepower is $\frac{20 \times 60 \times 160}{2,100} = 91.4$. These formulas, it will be remembered, are based upon a working tension of 60 and 45 pounds per inch of width, respectively.

The stress on a belt per square inch of section may be found by dividing the number of foot-pounds transmitted per minute by the velocity in feet per minute multiplied by the area of cross-section. In the foregoing case it is

$$\frac{33,000 \times 91.4}{5 \times 160 \times 3.1416 \times 20 \times .375} = 160$$

pounds, the thickness of the belt being taken at $\frac{3}{8}$ inch.

It frequently becomes desirable to know the velocity required to transmit a given horsepower with a given tension on the belt. This may be found by dividing the number of foot-pounds transmitted per minute by the tension on the belt. Suppose we wish to transmit 91.4 horsepower by a belt 20 inches wide having a tension of 60 pounds per inch of width. The velocity will be

$$\frac{91.4 \times 33,000}{60 \times 20} = 2,513.5 \text{ feet per min.}$$

Suppose the pulley on the engine shaft is 5 feet in diameter, at what speed must the engine be run? This may be found by dividing the velocity of the belt, in feet per minute, by the circumference of the pulley, also expressed in feet; the quotient will be the revolutions per minute. A 5-foot pulley will make, under the above conditions, $\frac{2,513.5}{5 \times 3.1416} = 160$ revolutions per minute.

It is quite important that the person in charge of belts should know how to make a good joint, both laced and glued. Laced belts are rapidly going out of use, particularly main driving, and nearly all dynamo belts. Even when a belt is laced with a good composition lacing, it is not altogether reliable, and when belts are used for driving blowers for cupolas and dynamos, or for the main drive in a factory, the ends should be glued and riveted together. When the belt is quite thick, the joint may be made in the manner indicated in Fig. 1. The ends of the belt are first drawn together by means of clamps, as shown in Fig. 2. It is sometimes desirable to introduce scales into the clamp rods so as to be able to determine the tension to which the belt is being subjected. This, of course, is not necessary for a person having practical experience, and is seldom done. A belt should not be drawn up so tightly but that it will have at least 3 inches sag in 20 feet. When making a splice, one end of the belt is split a distance equal to the width of the belt, provided it is not heavily loaded, otherwise make the length of the splice one and one-half times the width of the belt. The opposite end is then tapered down to a thin edge, beginning at such a distance from the edge that the tongue will just fit into the split end, otherwise the belt at the joint will be either too thick or too thin. After fitting the ends, which should be done on a smooth flat surface, the ends of the belt where they

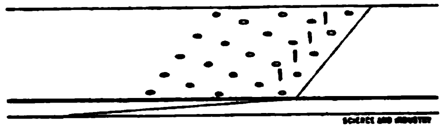


FIG. 3

come in contact with each other are given a coating of hot glue and pressed tightly together. Before the glue cools, shoe pegs may be driven in as indicated in the drawing in Fig. 3. These will tend to hold the layers of leather tightly together, the pegs becoming glued in place when driven in. After the glue has hardened so that there is no danger of disturbing any part of the joint, the copper rivets may be put in.

A thick belt, from four to seven ply, should be allowed from 24 to 48 hours after being entirely finished, in which to dry thoroughly and permit the glue to become hard before the clamps are removed. It is a good plan to allow the belt to run slowly, under a light load for a few minutes, before subjecting the joint to the full tension. The joint shown in Fig. 4 is suitable for belts of less thickness, the method of making the joint, however, is the same.

There are many styles of laced joints in use which have given good satisfaction, several of which were illustrated in the June number of SCIENCE AND INDUSTRY, but as laced joints are fast

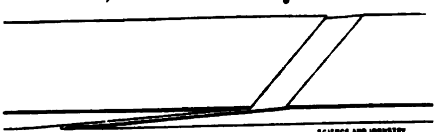


FIG. 4

becoming a thing of the past in large and important belts, one other style of lacing only is illustrated, which may be modified to suit the taste, or the

requirements. The lace leather or wire, if a composition lacing is used, is put downward through the holes *a*, *A*, as shown in Fig. 5, then up again through

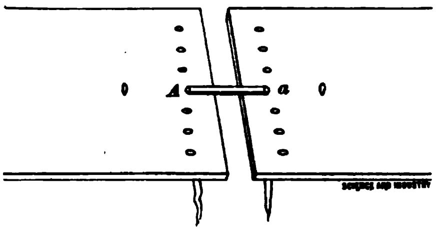


FIG. 5

the same holes, as shown in Fig. 6. The ends of the lace are then put downward through holes *b* and *B*, Fig. 6, and up through *c* and *C*, continuing in this manner to the outer edge of the belt, when the end *Y*, which will then be up at *d*, is carried across the joint and put downward through the hole *D* and up again through the hole *e* and so on back to the holes *a*, *A*. The joint, when half finished, will appear as shown in Fig. 7. The opposite side is laced in the same manner. When returning to the center, the lace will cross on the top side of the belt, leaving the bottom lengths parallel, as shown in Figs. 7 and 8. The dotted lines in Fig. 7 indicate the course of the lace when carried back to the center holes *a*, *A*. Here the ends are again put downward and brought up through the holes *e*, *E*, Fig. 7, and pulled through an inch or so, the ends

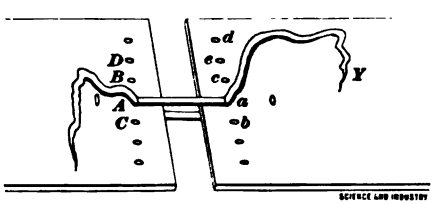


FIG. 6

being sometimes notched, as indicated in Fig. 9, for the purpose of preventing them from passing downward through the belt. With this style of lacing an odd number of holes is employed, and frequently every other hole is punched farther from the edge of the joint, as indicated in Fig. 8. When a belt is heavily loaded and the holes must be punched close together, it is obvious that some advantage may be gained by this method. In the drawings the ends of the belt are represented some distance apart; this being done to more clearly indicate both the upper and lower portions of the lacing. In practice, the ends are drawn closely together. When one style of lacing is well understood it is not difficult to devise several other methods which may have special advantages under certain conditions.

A great deal of trouble is oftentimes

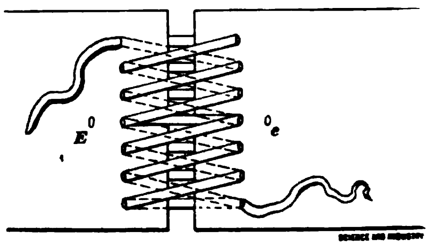


FIG. 7

experienced because of belts running off the pulleys. This may be due principally to three causes; namely, the pulleys may be out of line, or the belt may have become hard and dry, in which case the tendency to run off is due to slipping, and lastly, the belts may have been run off, and on to the pulleys just after receiving treatment for restoring the pliability or when they were new, or had been relaced and pulled up too tightly and unevenly, which results in unequal stretching. The remedy in the first instance is very apparent. The remedy in the second case consists in restoring sufficient adhesion to prevent slipping. This may be accomplished in four ways: First, by increasing the arc of contact

by increasing the size of the pulleys. This would be advisable were one of the pulleys of very small diameter. Second, by increasing the arc of contact by applying a tightener or idler near the driven pulley. Third, by increasing the initial tension so as to take out much of the sag on the top side when the belt is running. Lastly, by applying a suitable oil or other preservative, which will restore the necessary adhesion in many instances, without making any changes whatever. The last method mentioned should be applied first, and should it fail to produce the desired result, the others may be given a trial. These should not be resorted to until the belt has been put in good condition otherwise, for by so doing much time and expense for pulleys, idler frames, etc., may be avoided.

The remedy in the third instance is not so easily applied. The lengths of the two sides being unequal, one side is subjected to a greater stress when in motion and gradually works over on the pulley in the direction of the tight side. Which of the given methods will satisfactorily restore the belt to its proper condition will depend on the size of the belt, the speed, the thickness, and the extent to which the short side must be lengthened. This must necessarily be left to the judgment of the person in charge of the belts. If one side has been only slightly lengthened the short side may be stretched by applying a suitable oil to one-half the width of the belt, that is, throughout the length of the belt, but only on the shorter side. When both sides become of equal length the tendency to run off will cease and the belt will run in the middle of the pulleys. Care must now be taken lest the shorter side stretch too much and thus cause it to run off on the opposite side of the pulley. This, however, must be avoided by applying the oil in the proper quantities to what was the longer side, so as to cause the belt to

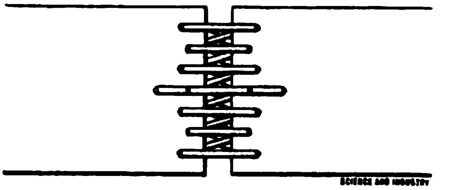


FIG. 8

stretch evenly. In order to treat a belt in this manner, which may be accomplished without stopping, it must be carefully and continually watched, and the oil, or other dressing, applied by some one who understands the requirements. Lacing the belt tighter on the shorter side, and stopping it frequently for examination, will also equalize the length of the two sides. If the belt is a small one, running at a moderate speed, and the inequality be not excessive, it may be remedied by running the belt off and on to the pulleys from the opposite side of the latter.

When belts are laced or spliced while in place on the pulleys, being drawn up tightly by means of belt clamps, they should not be run off and on to the pulleys. When it becomes necessary to remove a belt large enough to require lacing or splicing in this manner, a section of one of the shafts

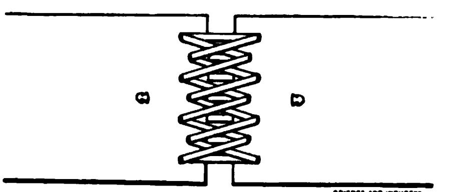


FIG. 9

should be moved over sufficiently to allow the belt to be slipped off when not in motion. Not a few large and costly belts have been rendered almost

useless, and have become exceedingly troublesome, by neglecting to take these precautions.

Manufacturers frequently prefer to

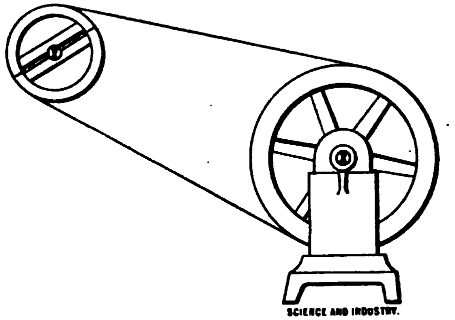


FIG. 10

use a tightener close to the driven pulley for the purpose of obtaining adhesion instead of increasing the initial tension when lacing or splicing. When the tightener is drawn away from the belt, the latter will have considerable sag so that it may be slipped off the pulleys when not in motion without straining it. When belts are not needed during the time the machinery is in operation, it is common practice to throw them off the pulleys and hang one end on some convenient part of the machine, allowing the revolving shaft to carry the weight of the belt. This is objectionable, for the wear then comes at one point on the belt, and if the shaft has a dull surface, the wear is apt to be considerable, which will materially weaken the belt at this point. A better plan is to arrange hooks or belt holders near the pulleys, located so that the belt, when not in use, will not touch the shafts or the pulleys.

It is quite important that the person having charge of the belts should know how to calculate the size of pulleys in order to obtain any speed that may be needed. Suppose an air compressor is purchased, which is to be driven directly from the shafting, as shown in Fig. 10, the speed of which is 220 and that of the compressor 140 revolutions per minute. In nearly all manufacturing establishments there are a number of unused pulleys that have accumulated as the result of changes, which from time to time become necessary when new machinery is installed, or when changes in the rate of production are made. If the diameter of the pulley on the compressor is 44 inches, what size pulley must be looked for, for the driving pulley on the line shaft? The diameter of a pulley, whether the driver or the driven pulley, may be found by the following rule: Multiply the diameter of the driven pulley (in this case) in inches by the number of revolutions per minute, and divide the product by the speed of the line shaft; the quotient will be the diameter of the driver in inches. Now, if the diameter of the compressor pulley had been required, the speed of the compressor would have been substituted for that of the line shaft. It will be seen that separate rules are not necessary for finding the diameter and speed of both the driver and driven pulleys, but

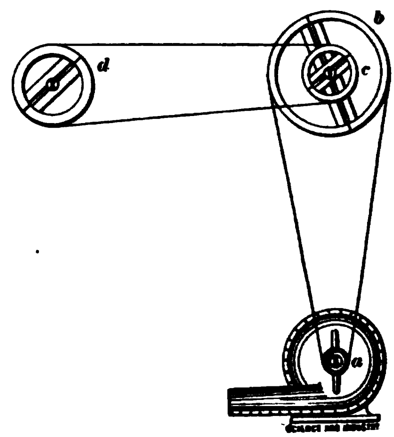


FIG. 11

merely the substitution in the division of speed for diameter, and vice versa. In the case assumed the driven pulley is 44 inches in diameter, and is to make

140 revolutions per minute, then we have $44 \times 140 = 6,160$, which is to be divided by the speed of the line shaft, which is 220 revolutions per minute, and the diameter of the driving pulley is thus found to be $6,160 \div 220 = 28$ inches.

After looking over the assortment of pulleys, if one of the proper size cannot be found a new one will have to be procured or the one on the compressor changed. Before ordering the new one it will be a good plan to find out just what speed this shaft is making when the full load is on the engine, and when the maximum amount of air is likely to be needed. The line shaft is supposed to make 220 revolutions per minute, but under the full load, the engine may run one revolution per minute slower, and if it is a Corliss engine with a large fly wheel, a variation of one revolution may reduce the speed of the shaft to, say, 212 revolutions per minute. If this proves to be the case it will make some difference in the size of the driving pulley, which is found by the same rule. The driver in this case will have to be $44 \times 140 \div 212 = 29$ inches in diameter instead of 28, in order to compensate for the loss in speed at the engine which is likely to occur at a time when the compressor

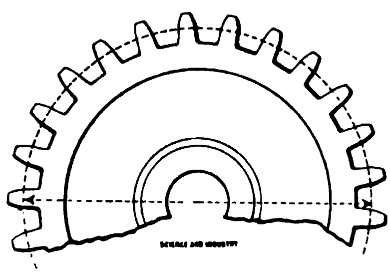


FIG. 12

should be working to its full capacity.

Take another case, this time a blower for a blacksmith's forge, as in Fig. 11, which is to make 1,400 revolutions per minute. The diameter of the pulleys are as follows: $a = 3$ inches, $b = 15$ inches, and $c = 8$ inches. What must be the diameter of the pulley at d? Assume

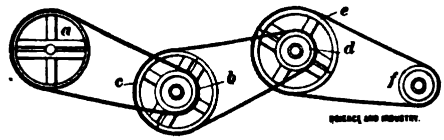


FIG. 13

the blower to be used in the same factory and that the minimum speed of the pulley d will be about 212 revolutions per minute, as previously obtained. We may begin with the blower, the same as with the compressor, and to find the speed of b, we have $1,400 \times 3 \div 15 = 280$ revolutions per minute. Now, as pulleys b and c are keyed on the same shaft they will make the same number of revolutions per minute, and the calculation for c is $280 \times 8 = 2,240$. Since the diameter is required in this case the speed of the pulley d is substituted for its diameter in the divisor, and the diameter is found to be $2,240 \div 212 = 10.5$ inches. When the speed of a machine must be got within narrow limits the thickness of the belt should be added to the diameter of the pulleys when making the foregoing calculations.

The speed of gearing is obtained in the same manner as that of pulleys for belt driving, and the diameters of gears, or the number of teeth, are found by the same rule by substituting the words "number of teeth in the driver," etc., for the "diameter of the driver," as used in connection with belting. For instance, if the driving gear contains 64 teeth and makes 100 revolutions per minute, and the driven gear contains 16 teeth, the speed of the driven gear will be $64 \times 100 \div 16 = 400$ revolutions per minute. Suppose we wish to find the number of teeth in a pinion which is to make 400 revolutions per minute, with a driver having 70 teeth

making 80 revolutions per minute. We would then have $70 \times 80 \div 400 = 14$ teeth in the pinion, the teeth having the same pitch as those in the

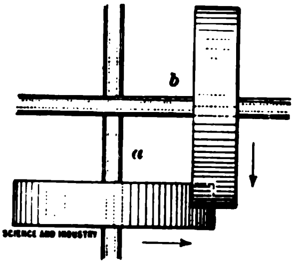


FIG. 14

driver. When the speed of gears is to be calculated by means of the diameter, the pitch diameter indicated in Fig. 12 should always be taken.

Expressing the rule for finding the diameters and speeds of pulleys and gears in the form of simple formulas that can be more easily remembered or referred to, we have for the speed of pulleys $\frac{P \times R}{p}$ = revolutions of small pulley. $\frac{P \times R}{r}$ = diameter of small pulley. For the number of teeth and speed of gears we have $\frac{T \times R}{t}$ = revolutions of small gear, and $\frac{T \times R}{r}$ = number of teeth in small gear.

P = diameter of larger pulley;
R = revolutions of larger pulley;
p = diameter of smaller pulley;
r = revolutions of smaller pulley;
T = teeth in the larger gear;
R = revolutions of the larger gear;
t = teeth in the smaller gear;
r = revolutions of smaller gear.

It will be seen that if we substitute the larger letters for the smaller ones and vice versa, we will obtain the revolutions and diameter, respectively, of the larger pulley or gear, as the case may be.

It will be noticed in connection with the rules for finding the speed of pulleys and gears that the speeds are proportional to the diameters—that is, if a pulley 6 feet in diameter drives a pulley 3 feet in diameter, the speed of the driven pulley will be twice that of the driver, because the speed of the driven pulley will be as much faster or slower than the driver as the diameter of the driven pulley is smaller or larger than that of the driver. In a drive arranged as in Fig. 13, the speed of the last pulley for one revolution of the driver is found by multiplying together the diameters of the driving pulleys and dividing the last product by the continued product of the diameters of the driven pulleys. Thus, $\frac{a \times c \times e}{b \times d \times f}$ = the revolutions of f, for one revolution of a. The letters in the formula refer to the diameters of the pulleys to which they correspond.

When finding the speed of gearing, the speed of the last pinion relative to that of the first wheel is obtained by dividing the continued product of the number of teeth in the drivers, or gear-

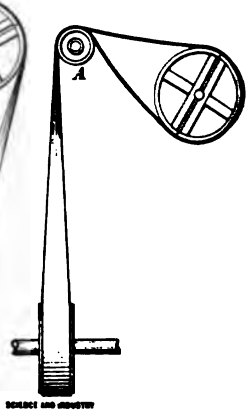


FIG. 15 FIG. 16

wheels, by the continued product of the number of teeth in the pinions. When substituting the diameter for the number of teeth in the case of gearing,

the pitch diameter should always be used.

Setting pulleys for a quarter-turn drive is a part of the work of the belt doctor, and if one or two points are remembered it is not a very difficult thing to do. Suppose we wish to drive shaft a from shaft b, Fig. 14, the former being at right angles to the latter. In the first place, it matters not at what angle the drive as a whole is placed. The center of the face of one pulley should fall directly over the corresponding point on the other pulley, as illustrated in Fig. 14. It will be seen that, when the pulleys are so placed, the belt will run squarely on to the driven pulley. This arrangement, however, will not allow of the motion being reversed. The direction of rotation of the two pulleys is indicated by the arrows.

By an inspection of Figs. 15, 16, 17, and 18 it will be seen that the same relative position of the pulleys must be had whether driving directly, or by means of a mule shaft and guide pulleys, as at A, and also regardless of the angle at which the shafts lie to each other.

FIG. 17

When a machine is not in motion the length of a belt may be quickly and accurately measured by passing a tape line around both the pulleys, making some allowance for the proper sag, which in a belt in good condition and in order to keep the friction as low as possible may be taken as .15 times the distance between the centers of shafts in feet to start with. But it frequently happens that a new belt must be put on during the noon hour, or during some stoppage of the machinery when time is equally limited. In this case it is not practicable to obtain the length of a belt by means of the tape, so that the machinery must either be stopped or the length of the belt obtained by calculation. With an open belt and pulleys of about the same diameter this becomes a simple matter and is obtained by adding together the diameters of the driver and driven pulleys, then multiplying one-half the sum by .2618; the product will be the length of the belt in contact with the two pulleys. It is evident that twice the length of the belt L, or twice the distance between the centers of the pulleys, as indicated in Fig. 19, must now be added to that on the pulleys in order to obtain the total length of the belt. Expressing this rule in a form more easily remembered, we have $\frac{D+d}{2} \times .2618 + (L \times 2) =$ length of belt in feet, in which $D =$ diameter of driving pulley, $d =$ diameter of driven pulley, and $L =$ the distance between centers.

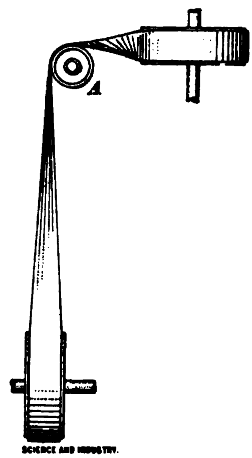


FIG. 18

When a crossed belt is employed a different method will be adopted, because the belt runs at a considerable angle to the center line oo, Fig. 20, and will therefore be somewhat longer. One rule is: Add together the radii of the pulleys in feet and divide the sum by the distance between the centers of the shafts also expressed in feet; in a table of natural sines find the angle that most

nearly corresponds with the quotient, and call the result 1; multiply this angle by the decimal .0349 and add the product to 3.1416; call this result 2;

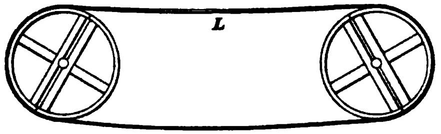


FIG. 19

multiply twice the distance between the shafts by the cosine of the angle previously obtained, and call this result 3; then multiply the sum of the radii by result 2, and add result 3; the sum will be the length of belt required. To illustrate this rule, suppose two pulleys of 6 and 4 feet diameter, respectively, are run by a crossed belt, at a distance of 18 feet between the centers. Following the rule we have, $\frac{6}{2} + \frac{4}{2} \div 18 =$ .2777, and in a table of sines the nearest angle corresponding to it is found to be 16 degrees, which is result 1; then $.0349 \times 16 + 3.1416 = 3.7$, which is result 2; the distance between the centers of the shafts is 18 feet, and the cosine of 16 degrees we find is .9612, therefore $18 \times 2 \times .9612 = 34.6$ feet, which is result 3. The rule says that the sum of the radii is to be multiplied by result 2, and result 3 added to the product; doing this we find the length of the belt is equal to $5 \times 3.7 + 34.6 = 53.1$ feet, or 53 feet $1\frac{1}{4}$ inches.

Where belts are kept rolled, the length of the belt in each roll should be marked upon it, for it is not always convenient to unroll belting on the floor in order to measure it. When it is necessary to find the number of feet of belt in a roll that has not been marked (it should be closely rolled), it may readily be estimated by applying the following rule: Add together the diameter of the roll and the eye, both in inches, multiply the sum by the number of turns in the roll, and by the decimal .1309; the product will be the length in feet.

A strip of single belting 1 inch wide and 13 feet long weighs, approximately, 1 pound, and a similar strip of double belting 8 feet long also weighs a pound, so that the weight of a belt may be estimated by multiplying the width in

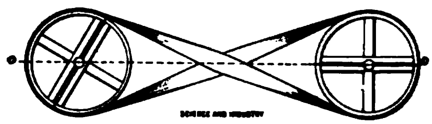


FIG. 20

inches by the length in feet and dividing the product by 13 for single and 8 for double belts; the quotient will be the weight in pounds.

N. A. S. E. CONVENTION

The Twenty-First Annual Convention of the National Association of Stationary Engineers will be held at Boston from September 2d to 5th.

The transportation committee has contracted with the Wabash, West Shore, and Boston & Maine Railroads as the official route from Chicago and intermediate points, these roads having granted a fare of one and one-third for the round trip.

The headquarters of the general committee will be in Room 14, Engineering Building B, of the M. I. T., Trinity Place, and will be open from 8.30 A. M. to 10.30 P. M., daily. The exhibition of mechanical goods will be held in Engineering Buildings A and B. SCIENCE AND INDUSTRY will occupy one of the largest booths in the hall, where we shall extend a cordial welcome to all visitors.

ECONOMY AND THE QUALITY OF FUELS

R. T. STROHM

THERE is one question which is always first in the mind of the user of steam power, to discussions of which he is ever ready to give respectful attention. This is the cheapening of the cost of power, and it arouses a potent interest because it directly concerns the pocketbook of the power-plant owner.

The cheap production of power demands that certain conditions obtain. In the first place, there must be economy of operation, which in itself necessitates good, clear-headed management. In the second place, there must be efficient apparatus to accomplish the work. This does not necessarily imply the maximum possible efficiency, but rather the highest efficiency consistent with the nature of the work, the investment, and the returns expected.

The term economy is often wholly misunderstood, judging from the attempts which are made to practice it. There are many who evidently believe it to be synonymous with the greatest possible saving. No greater mistake could be made. True economy involves spending, as well as saving. It is a spending to increase returns, and it is a saving of wastes to accomplish the same purpose. The hoarding of every possible cent, regardless of the condition of the machinery or the efficiency of the plant, is false economy. That plant which, after deducting the interest on investment, the depreciation in value due to usage, and the cost of repairs necessary to maintain an undiminished efficiency, can show the greatest earnings per horsepower certainly should be considered the most economical.

The question of cheap steam generation, then, resolves itself into a study of the conditions of working of the steam boiler. And since the boiler constitutes the first step in the transformation of heat energy, it is but natural that any investigations tending toward a lessening of cost in production should begin at this point.

The question of fuel quality is probably the first one to arise. Under a given set of conditions, the cost of operation of the boiler, such as the firing, inspection, cleaning, and so on, cannot well be reduced to any great extent, without danger of loss through inefficient labor. Naturally, then, a lowering of expenses by using a cheaper grade of fuel will be the next point to be considered. The subject is a most attractive one, and involves many interesting features.

At first thought, one would be inclined to believe that the fuel which developed the greatest number of thermal units at the least cost would be the most economical for general use. Theoretically, this is true enough, but the statement has several important limitations when the conditions of actual practice are taken into account.

Let us consider just what is involved in substituting for a good fuel another of less cost per ton, and of a lower calorific value. Assume a change from semibituminous coal of calorific intensity of 13,500 heat units per pound to a bituminous coal capable of producing only 10,000 heat units per pound.

In each case, a certain definite and unvarying amount of heat energy must be generated to perform the work of the steam plant. Therefore it will require a greater amount of the cheaper fuel to produce this heat than it would of the higher grade. In other words, it will be necessary to burn more coal

per hour, and the increase in coal consumption, all other things remaining the same, will be $\frac{13,500 - 10,000}{10,000} = \frac{3,500}{10,000} = .35$, or 35 per cent.

As a consequence of the change, then, it is now necessary to fire more than one and one-third tons of coal where previously one ton had been fired, and in a plant of even ordinary size this means a considerable increase in the work of firing. It is here that we meet with the first obstacle to the adoption of a low-grade fuel.

No self-respecting fireman will willingly consent to a 35 per cent. increase in his labors (assuming that the boiler is hand fired), without some advance in wages for the extra effort entailed. The word "willingly" is used for the very reason that there are men who, under the pressure of necessity, will submit to almost any imposition on the part of unprincipled and unscrupulous employers, rather than be out of work altogether. In any such case as this, the employer is the loser in the long run, even though he may not realize it. For an underpaid, overworked fireman has little incentive or ambition to be either economical or efficient, and there are a hundred ways in which he can cause, or at least allow, losses that in the end will sum up to a very considerable total in the expense account.

To maintain an efficient fireman, then it is necessary to expend a certain portion of the saving due to cheaper fuel in compensating for the increased labor of firing.

If a mechanical stoker is used, it is still necessary to spend more for firing. For the power to run the stoking apparatus will be increased in direct proportion to the increase in fuel consumption, and the cost of this power must be proportionately more. At the same time the increased wear and tear on the stoker itself, due to the more rapid operation, must be taken into account. All this will decrease the apparent saving indicated by the difference in the cost of the two grades of fuel.

The products of combustion of the cheaper fuel will be far in excess of those of the higher grade, and as a consequence there will likely be trouble regarding the draft. The gases, while at a lower temperature in the case of the low-grade coal, will be greater in volume. Now, the draft must be of such intensity as to remove these gases rapidly. But, with natural draft, the draft pressure is dependent upon the temperature of the flue gases, and since this temperature has been lowered by the change in fuel quality, the draft intensity has been also decreased.

The condition that is thus brought about is such that the intensity of the draft must be increased to take care of the larger amount of flue gases, and this necessitates either a new or a higher chimney. To add to the height of the existing chimney is perhaps the easier way out of the difficulty, but the cost of such an operation must be deducted from the amount saved in fuel, to obtain the actual net saving.

If forced draft is used, it will still be necessary to expend more power for draft purposes, since the fan will need to be speeded up to produce an increased pressure for the removal of the greater volume of gaseous products.

Where natural draft is employed, the greatest rate of combustion of fuel is determined by the height of the chimney, and it may be added that at present natural draft is far more generally used than forced draft. With bituminous and semibituminous coals, the maximum rate of combustion under the best conditions is $F = 2.25\sqrt{H}$, in which F is the

number of pounds of coal burned per square foot of grate per hour, and H is the height of the chimney in feet. To increase the amount of coal burned by 35 per cent., then, without any alteration in the height of the chimney, will result in what is commonly termed as forcing the boiler, but which would be more reasonably called forcing the fires.

This forcing cannot result otherwise than to decrease the efficiency. The volume and the velocity of the gases being greater, they are in contact with the heating surface for a shorter period, and consequently have not the same opportunity to give up their heat to the boiler as was possessed by the gases from the semibituminous variety. Further than this, their temperature is considerably lower, and since the transfer of heat varies directly as the difference of temperature, the efficiency of the heater will be reduced.

To obtain the best results in the way of combustion, it is necessary to regard the following points: First, to fire regularly and often, rather than in larger quantities at longer intervals. Second, to maintain a bright, clean fire, which involves keeping the air spaces in the grates free and open, so as to allow an unrestricted passage of air through the bed of coals on the grate. Third, the ash-pit must be kept as free from accumulations of ashes and clinker as possible.

As a usual thing, the cheaper the grade of fuel the greater will be the amount of ash and clinker. The latter will fuse to the grate bars and choke the air passages, lessening the amount of the air supply, and making it extremely hard to maintain a clean, bright fire. The effect of the repeated cleaning necessary is to cause more wear and tear on the grates, and loss of fuel by its falling through the air spaces.

The use of the cheaper coal entails an increase in the heat waste. Inasmuch as more coal must be fired, the doors of the furnace must be opened more frequently, and in that way the temperature of the interior of the furnace undergoes more frequent changes due to the inrush of cool air. This causes a heat loss. Further than this, the shell of the boiler and the firebrick walls are subjected to the same alternate heating and cooling, and as a result, the deterioration is far more noticeable and rapid. The natural consequence is frequent renewal of the furnace linings and arches, and a shorter life of the boiler.

Owing to the increased amount of ash and clinker, the fireman will find it difficult to keep the ash-pit as clean and free from large accumulations of refuse as is desirable. For if the hot ashes be allowed to remain in the ash-pit until they are cool their heat may warp the grate bars.

The cost of disposing of the refuse from the fuel must be considered, too. In case the plant is located in a region where the land is not extremely valuable, so that the ashes may be dumped near the boiler house, this consideration will not be of much consequence. But if the plant be located in a city, where the refuse must be carried several miles, the question of ash disposal becomes an important one, and in reckoning the economy the increase in the cost of ash haulage must be taken from the amount of reduction in the coal bill.

Another point to receive attention, in the case of the large plants, is the increase in the capacity of storage bins for coal when a cheap fuel is substituted for a better grade. Or if such increase is impracticable, then there will be a greater danger of a failure in

the fuel supply, in case of such an emergency as a protracted miners' strike or a temporary disability of the means of transportation.

A reduction in the quality of fuel need not necessarily lower the efficiency of a boiler provided the grate surface is increased and the boiler setting changed to conform to the new conditions of combustion. This is generally an expensive operation, and not justified unless the change of fuel is to be a permanent one. But in any case, where the boiler has been designed to burn a certain grade of fuel, a lowering of this grade without a corresponding alteration of the boiler setting can only result in a loss of efficiency.

FUSES

PRINCIPLE OF ACTION—FUSE WIRES—MODERN FUSES

IN certain kinds of valuable and complicated machinery, a safety rod is provided so that in case the machine is overloaded the rod will break before

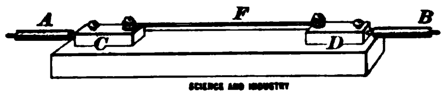


FIG. 1

the more expensive portions of the machine become injured. The broken rod can be easily removed and a new one substituted. The machine will then again be operative. In electrical work the fuse acts as a safety bar, protecting the apparatus and wires on the circuit in which it is installed.

When a current of electricity is passed through a wire, it has been found that a certain amount of electrical energy is expended in forcing the current through the wire against the resistance offered by the wire. This energy appears in the form of heat. If the rate at which heat is evolved is so great that it cannot be conducted away from the wire by conduction and radiation fast enough, the wire will rise in temperature, and if the temperature rises to the melting point of the wire, the wire will melt and open the circuit. Joule found that the number of units of heat developed in a conductor carrying a current is proportional to its resistance, the square of the current, and the time that the current flows.

The equation expressing these relations is known as Joule's law, and is $A = C^2RT \times .24$. C equals current in amperes, R equals resistance in ohms, T equals the time in seconds, and A the heat in calories. As the heating effect varies as the square of the current, a comparatively small change in the current will cause a large variation in the heat evolved and the rise in temperature of the wire.

Short lengths of wire are installed in a circuit so that if for any reason the current in the circuit becomes excessive the small pieces of wire will melt, or blow, thus protecting the apparatus connected in the circuit. These wires are called fuse wires and are made of several different metals and alloys. Ordinary fuses are usually made of a mixture of lead and bismuth and vary greatly in composition, some fuses

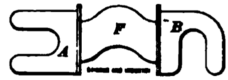


FIG. 2

being much harder than others. Copper fuses are generally used on electric street cars. Aluminum fuses have been used for alternating-current work.

For wires of a given material, the current needed to raise them to an equal temperature varies approximately as the square root of the cube of the diameter.

Fuses are usually mounted on an insulated base and so enclosed that the melted fuse metal cannot fly out when the fuse blows. They are placed on both line wires so as to protect the main circuit, and on the line wires of the various branch circuits. The sizes of the fuses are proportioned to the conductors they are intended to protect, so that they will melt before the maximum safe-carrying capacity of the wire is exceeded. Fuses must have contact surfaces or tips of harder metal, having perfect electrical connection with the fusible part of the strip. The fuses must be stamped with about 80% of the maximum current they can carry indefinitely, thus

FIG. 3

allowing about 25% overload before the fuse melts. The fusing current for certain sizes of copper wires is given in the accompanying table:

B. S. Copper Wire	Fusing Current in Amperes
17	100
16	120
15	140
14	166
13	200
12	235
11	280
10	335
9	390
8	450
7	520

In early wiring practice the fuse consisted simply of a round piece of wire made of fuse metal and was connected to terminal blocks at each end of the fuse block. If the fuse melted the remaining portions of the fuse were removed from connection with the terminals, and another length of fuse wire inserted and fastened in place by the screw and washer clamps.

In Fig. 1, *A* and *B* represent con-

FIG. 4.

ductors connected to a fuse block, *C* and *D* the metal terminals, and *F* the piece of fuse wire.

This method of securing the fuse wire to the terminals is not very satisfactory, as a poor electrical connection may be made between the terminal pieces and the fuse wire and therefore cause heating, due to the current flowing through the contact resistance. In several cases if there were no fuse wire on hand to replace a burned-out fuse, a

FIG. 5

nail or large copper wire was used, thus giving no protection to the circuit. The amount of current that is required to blow a fuse wire of a certain size is

not at all constant. It depended on the length and uniformity of cross-sectional area, the proportions of the various metals that make up the fuse metal alloy, its exposure to air currents, and the connections with the fuse-block terminals. The fuse wire would blow if a short circuit occurred, but it might not blow for a steady and dangerous overload. Fuses are often made in the form of links that can be readily connected to the fuse block. Fig. 2 shows a fuse link, where F represents a strip of fusible metal, and A and B copper fuse terminals which are connected to the fusible portion. The flat fuse terminals A and B are securely screwed down on the fuse-block terminals, thus making a good electrical connection.

Link fuses are very easily installed. A fuse very generally used at the present day is the enclosed fuse. The fuse wire is enclosed within an insulating shell. The space between the fuse and shell is filled with an insulating, non-combustible substance. The fuse is protected from air currents and is more reliable in regard to its blowing point. When the fuse burns out there is no destructive arcing. This type of fuse has many advantages over the old-style open fuse, and is installed very largely on new work. A single enclosed fuse is shown by Fig. 3.

Fuses are installed in many different ways in connection with fusible plugs, cut-outs, switches, panel boards, etc. It is not the intention in this article to give detailed descriptions of these pieces of apparatus, but in Fig. 4 is shown a two-wire main, six-circuit panel board, using combined switch and fuse carriers. When a fuse blows the carrier, Fig. 5, may be removed, a new fuse inserted, and the branch circuit closed by replacing the carrier in its proper position on the panel board. The danger of short-circuiting the mains is thus obviated, as the new fuse is installed when the carrier is removed from the panel board.

POWER IN THE SOUTHERN COTTON MILLS

GEORGE E. WALSH

THE cotton manufacturing industry of the South has assumed such importance in the past five years that the question of power to operate the mills has become one of the foremost questions of the day. Within ten years the spindles have been increased from a million and a half to over five millions in about a dozen of the cotton-raising states, and nearly all of the new mills are equipped with the latest and most improved machinery. When the cotton-spinning industry first started in the South, it was largely an experimental question, and the mills were chiefly makeshift affairs, with second-hand machinery installed in them; but today the new mills represent the highest achievements in this line. They are equipped with all modern methods for spinning and dyeing cotton goods. It was found that the old machinery not only proved unsatisfactory in its work, but it was such a drag upon the plant that losses were frequently incurred which the new machinery had to make good.

In view of the fact that cotton spinning is bound to increase rapidly in the next decade, the fuel question has been seriously studied, and a few facts about it may be of value. One of the early inducements which made manufacturers locate in the South was the

constant water supply of the rivers and streams. In some of the states, notably the Carolinas, the water power is sufficient to operate many of the mills the year around. But the number of mills situated on the course of the streams has taxed the water power to its utmost, and most of the mills have in the past few years been installed with steam and electric plants. During the season of the year when the water supply is low, steam is used almost exclusively, and at other mills electricity is only employed for lighting and operating small engines.

The equipment of the mills with steam and electric power places them in a position of independence which prepares them for almost any emergency. Fuel has always been comparatively cheap in the South, and both wood and coal have been used; but the cost of getting the coal to the mills is annually increasing. The Southern pine woods, which furnished wood as fuel in such abundance, are now rapidly being destroyed around the cotton belt, and the cost per horsepower where wood fuel is used will soon reach a point where it must be abandoned.

At present water power is the cheapest and this is used in many of the mills in generating electricity for the operation of the machinery. In fact, nearly all the machinery is constructed with the idea of using both electricity and steam direct. Some of the mills have installed machinery for generating electricity by steam power alone, and operating the machinery by a strong current distributed throughout various parts of the mills.

The need of technical education in the South has naturally increased in proportion to the number of mills constructed for manufacturing cotton products. So far, the two technical schools of the South have been unable to supply sufficient students and graduates to fill the positions opened for them in high-class mills. Both mechanics, engineers, and technical dyers and spinners are needed for the growing industry. The opportunities offered young mechanics are increasing with the development of the technical nature of the work. The newest machinery being installed in the mills performs double and triple the work that was possible by the old. The old machinery was slow in comparison to the new. With new spindles making eight to ten thousand revolutions, the old ones with their six to seven thousand cannot hope to compete. The substitution of higher power machines and spindles has increased the efficiency of the new mill some 20 to 30 per cent.

The operation of the mills must, to a large extent, depend upon the efficiency of the mechanics and machinists who have the machinery in charge, and the need of competent men for these duties has been more urgent in the cotton belt than for spinners and ordinary operators. A good deal of the machinery is of the most expensive type, and the question of caring for and preserving this is of considerable importance. Cheap wages have been given in the Southern cotton mills for spinners and ordinary operators, but high-class, efficient machinists, engineers, and mechanics have been paid wages of the highest. The mill owners have found that economy in mill practice does not include employing engineers of a cheap grade. Consequently, while the demand is for the highest and most efficient, the wages paid are correspondingly high. Good engineers and skilled mechanics are receiving in the mills from \$75 to \$100 per month, with some higher wages for those in the best mills. The cost of living in the South, near the cotton mills, is much lower than in

the North, and this is a factor that should be considered in comparing the wages of the two sections.

Probably the greatest demand in the cotton mills is for skilled mechanics and constructive engineers, who are capable of superintending the mill property without loss to the owners. Such men must be something more than mere mechanics who know their trade, they must be men who have the ability to put together and take apart the intricate pieces of the plant. The repair item has been such an important part of the expense account of the new mills that the owners have made special efforts to save their machinery by importing expert engineers and mechanics.

One of the growing features of the manufacturing in the Southern cotton mills is the production of new lines and patterns of cotton cloth for the Oriental markets. In order to accomplish this, it is necessary for inventors and designers to cooperate. In Germany the students who receive special instructions and experience in spinning and weaving new textile goods receive large salaries, and the government helps to support the technical schools which turn the experts out. As a result, the textile manufacturing of cotton and print goods in Germany for export markets is of the highest order. We have just begun to compete in the foreign markets with the products of these highly-refined textile mills of Europe, and to secure and hold the customers it is found necessary to exert ourselves to improve our methods of cotton spinning and weaving. We have in the past few years forged rapidly ahead in this field by virtue of our superior inventive faculty. New weaving, dyeing, and spinning machinery has been invented by Americans which accomplishes in a shorter time what European skilled experts have laboriously produced by older methods. At present our hopes are in continuing to improve our machinery, and in inventing newer methods of weaving and dyeing. On the other hand, the skilled operator and mechanic must come forward to make perfect the good work started by the inventors. The operation of the labor-saving machinery must be in the hands of experts.

The American inventor of cotton-manufacturing machinery has always stood preeminent in his field. Likewise the operators of the new machinery have been unsurpassed by any others in the world. The field for both broadens today in the great Southern cotton mills, and the opportunities for improvement and advancement for the expert, progressive genius and mechanic were never so enticing as today. Within the next decade conditions now existing in the cotton belt will be even more thoroughly revolutionized than they have been in the past ten years. The inventor, the mechanic, and the engineer are crowding to the front in a part of the country that was formerly given over almost entirely to agricultural pursuits. The New South will thus be the work of the inventor and mechanic, backed up and encouraged by capital and brains.

OVER-COMPOUNDING A DYNAMO

F. H. DOANE

REASONS—SHUNT TO THE SERIES-COILS—METHOD OF ADJUSTMENT OF THE SHUNT

IT IS desirable in either an electric-lighting system, or an electric-railway system, that the E. M. F. at central points outside of the station be kept at as nearly a constant value, at all loads, as possible. If the E. M. F. at these points varies greatly in value, the brilliancy of the incandescent lamps, connected to the lighting mains, changes through a considerable range. A variable E. M. F. is also undesirable on an electric-railway line.

All known materials, when used as conductors of electric currents, offer more or less resistance to the passage of an electric current through them. When a voltmeter is connected between the ends of a section of wire through which a current is flowing, the voltmeter will indicate that a pressure of a certain number of volts is required to force the current through the conductor against its resistance. The values of the current and resistance must be sufficiently high to cause an appreciable drop in volts, so that the voltmeter will indicate the volts drop by the reading. The drop in volts along a length of wire in a direct-current system is equal to the product of the value of the amperes flow of current and the value of the ohms resistance of the length of wire. As the current increases in the wire the drop in volts also increases.

Consider the case of a shunt-wound dynamo furnishing current to a 110-volt lighting circuit. The speed of the dynamo will be considered as practically constant at all loads within the range of the dynamo. We adjust the field rheostat so that the E. M. F. across the brushes is 110 volts before the main switch is thrown in. Now, keeping the field rheostat the same, we throw in the main switch and increase the load up to full load. The current now flowing through the armature conductors requires that a certain part of the total E. M. F. generated be expended in forcing the current through the armature coils against the resistance of these coils. The drop in volts in the armature is thus deducted from the total E. M. F. generated and the remaining E. M. F. is the terminal E. M. F. of the dynamo. The reduction in E. M. F. across the brushes and across the shunt-field coil terminals, reduces the current in the shunt coil, which lessens the magnetic flux through the armature, still further reducing the terminal E. M. F. Armature reactions also weaken the field flux and this effect increases as the load increases.

Now consider the E. M. F. at a central point some distance from the station. If there is little current flowing through the line and through the dynamo, the E. M. F. at the central point will be almost the same as the terminal E. M. F. Now, if the load on the line is increased and more current flows through the line wires, a drop in volts occurs along the line wires and the effective E. M. F. across the lamps is equal to the terminal E. M. F. minus the drop in volts along both line wires from central point to dynamo terminals. As the E. M. F. at the terminals is less at full load than at no load and there is a loss in volts in the line wires, the E. M. F. at the central point is much lower at full load than at no load.

In order to keep the E. M. F. at the central point the same at all times, the

E. M. F. at the terminals of the machine must be raised, as the load on the dynamo is increased. This increase in terminal E. M. F. must make up for the line loss, in volts, the volts lost in the armature and the result of the partial demagnetizing action of the armature reaction. As the terminal E. M. F. is raised the current in the shunt coil is increased which increases the magnetic flux and tends to increase the terminal E. M. F. This increase in E. M. F. might be brought about by decreasing the resistance in the field rheostat, thus increasing the current in the shunt coil, thereby increasing the field flux and the terminal E. M. F. The field rheostat can be adjusted by hand or automatically.

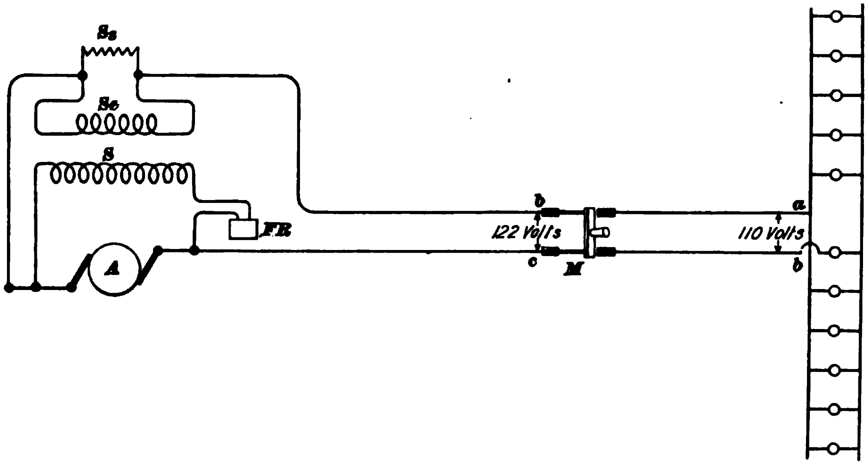
A better way of raising the E. M. F. of a line as the load comes on is to use a compound-wound dynamo instead of a shunt-wound dynamo. The field flux in the compound-wound dynamo is set up by two distinct sets of coils, the shunt coil, the terminals of which are connected across the brushes, and the series-coil, which has one terminal connected to one armature brush and the other terminal connected to the external circuit. In a compound-wound dynamo which does not have a shunt across its series-field, all the current that flows through the armature, with the exception of the proportionally small current used in the shunt coil, passes through the series-coil. If the load on the line increases, the current in the series-coil increases, and therefore its magnetizing action increases. This action increases the magnetic flux through the field and the armature conductors thus have set up in them a higher E. M. F. than the E. M. F. generated in them at no load. By properly proportioning the series-coil, their effect may be to simply raise the E. M. F. generated to such a value that the drop in volts in the armature winding and the demagnetizing armature reaction be just neutralized, so that the terminal E. M. F. at the dynamo remains practically constant at all loads. By increasing the number of turns of the series-coil the magnetizing action of the coil is increased and the E. M. F. generated in the armature increased at a higher rate than that necessary to make up losses occurring in the dynamo itself, so that the E. M. F. at the terminals increases as the load increases. This increased E. M. F. at the station allows the E. M. F. at a central point, outside of the station, to remain at a nearly constant E. M. F. The line loss increases as the current and load increases, but the dynamo terminal E. M. F. also increases as the load increases. These two effects may be made to neutralize each other so that the lamps some distance from the station may have an approximately even E. M. F. at their terminals. When a dynamo is arranged so that its terminal E. M. F. increases as its load increases, the dynamo is said to be over-compounded.

It is often convenient to have some means of readily varying the amount of over-compounding of a dynamo. This may be done by connecting an adjustable shunt resistance across the terminals of the series-field. Part of the current flowing from the armature to the external circuit passes through the series-coil and part passes through the shunt resistance, which is in multiple with the series-coil. By adjusting the resistance of the shunt, either a greater or a lesser proportion of the total current passes through the series-coil, and thus the over-compounding of the dynamo is changed.

Shunts are sometimes made of German-silver tape. A number of strips

are clamped together in multiple and the shunt connected across the series-coil terminals on the connecting board on the field frame, or between the terminals of each of the two end series-coils. In the latter case the shunt would lie in the space between two pole pieces. This form of shunt may be adjusted by varying the number of strips in multiple, or by increasing or decreasing the effective length of the shunt between the points where the series-coil terminals are fastened to the shunt.

The relative connections of the armature *A*, shunt-field coil *S*, field rheostat *F R* series-field coil *Se*, main switch *M*, and the shunt to the series-coil *Ss* are shown in the figure.



Suppose we have a compound-wound machine, provided with a series-shunt, which is adjusted for a certain loss on the line from the station to some central point, and we wish to adjust it for another value of line loss. We will take our line loss in volts, at full load, as 10 per cent. of the E. M. F. at the terminals of the dynamo. In order to have an E. M. F. of 110 volts at central point *a b*, the dynamo must have a terminal E. M. F. of $\frac{110}{90} = 122$ volts. This allows a drop in volts along the line of 12 volts, which is practically 10 per cent. of the dynamo terminal E. M. F. First run the dynamo up to its regular speed, with switch *M* open. Adjust *F R* until the E. M. F. at the terminals of the dynamo is 110 volts. There is now no current through the series-coil. Now throw in the load and increase to full load. Current now flows through *Se* and *Ss*. When running at full load it may be found that the E. M. F. across the terminals or at point *b c* is more than 122 volts. In that case add more strips of German silver, in multiple, to the series-shunt or diminish the effective lengths of the shunt between the series-coil terminal clamps. This allows the shunt to take a larger proportionate share of the total current and robs the series-coil of current, which will reduce the maximum terminal E. M. F. of the dynamo at full load. In case the E. M. F. is found to be lower than 122 volts across *b c*, at full load, increase the resistance of the shunt by decreasing the number of strips in multiple, or increasing the effective length between the series-coil terminal clamps. This will allow a greater proportionate share of the total

current to pass through the series-coil and increase the maximum E. M. F. at full load. After the shunt has been adjusted, clamp securely in place and insulate by wrapping it with tape. Compound-wound dynamos which are to be run in multiple must all be compounded or over-compounded to the same degree, so that the increase in E. M. F. of one machine as the load increases will be the same as the increase of E. M. F. of the other machines.

ELEMENTARY PRINCIPLES OF ELECTROMAGNETS—IV

Winding the Coils

IN PREVIOUS articles the magnetic circuit and the calculation of the ampere-turns required to produce a given magnetic flux have been explained. Let us now suppose that a coil containing the necessary number of turns is to be calculated. The way in which this should be done will naturally depend upon what quantities are known or given. For instance, the current and resistance may be specified, or only the voltage. If the size of the core is known, then the average length of one turn may be at least estimated by allowing a certain depth for the winding. If the current is known then the total number of turns can be readily calculated; since the ampere-turns, which is known, is equal to the product of the current and the turns. The number of turns multiplied by the mean length of one turn give the total length of wire required. The size of the wire may depend upon the resistance required or upon the amount of heat that can be safely radiated from the surface of the coil. With a given size wire and a given voltage it makes no difference, as far as getting the required number of ampere-turns is concerned, how many turns are used. For, if the number of turns be doubled, the resistance will be approximately doubled and the current will be reduced one-half, hence the number of ampere-turns is the same. There is, however, a disadvantage in using a short length of wire, as this requires a large current. Since the energy wasted in heating the coil is proportional to the square of the current and only proportional to the resistance, it is better to increase the length of wire, thereby increasing the resistance and reducing the current, so that the energy lost in heat may not be excessive. On the other hand, an excessive amount of wire is expensive and the weight to be used must therefore constitute a mean between the cost of energy for maintaining the current and the cost of copper in the coil.

Another consideration may also influence the amount of wire used, namely, the available space for winding. If a magnet is wound with too small a wire so that it heats excessively, there is not only the danger of charring and injuring the insulation, but the resistance may also increase so much as the coil heats up as to appreciably cut down the current. In this case the magnet may not be sufficiently excited when the coils are hot, if the coils were designed te take the proper current when cold.

Let E be the voltage of the source of current and $I\ T$ the ampere-turns required and previously calculated. Let us suppose that there is to be an adjustable resistance in series with the magnetizing coil, as in the field circuit of a shunt dynamo, and that the drop through this resistance, when it is all

in the circuit, is e volts. Then, if the mean length l of one turn can be calculated or estimated, approximately, the following formula may be used to calculate the sectional area A of the wire in circular mils (diameter in mils squared) for the magnetizing coil:

$$A = \frac{12 \times l \times IT}{E - e}. \qquad (1)$$

That is, the square of the diameter of the wire in circular mils is found by multiplying 12 times the mean length of one turn by the ampere-turns, and dividing this product by the difference between the total available electromotive force and the drop in volts through the regulating resistance. Having calculated the square of the diameter, the corresponding gauge number can be obtained from a wire table.

If there is to be no regulating resistance then e in the last formula drops out, and it becomes

$$A = \frac{12 \times l \times IT}{E}. \qquad (2)$$

The number 12 is derived from the resistance of 1 mil foot of copper, which at 75° F. is 10.5 ohms. In this formula a rise in temperature of 55° F. has been allowed, and the resistance of a mil foot is thereby increased to 12. This will be found to be a good general figure to use, but it may, of course, be modified to suit any other rise in temperature.

TABLE I

INSULATED COPPER WIRE

Number B. & S. Gauge	Diameter in Inches						Square of Diameter. Bare (d^2)
	Bare (d)	S. C. C.	D. C. C.	T. C. C.	S. S. C.	D. S. C.	
1	.289		.308	.307			.08369
2	.258		.272	.276			.06637
3	.229		.243	.247			.05263
4	.204		.216	.220			.04174
5	.182		.194	.198			.03310
6	.162		.174	.178			.02625
7	.144		.156	.160			.02082
8	.128		.140	.144			.01652
9	.114		.126	.130			.01309
10	.102	.108	.112	.116			.01038
11	.0907	.097	.101	.105			.008234
12	.0808	.087	.091	.095			.006530
13	.0720	.078	.082	.086			.005178
14	.0641	.070	.074	.079			.004107
15	.0571	.063	.067	.071			.003257
16	.0508	.055	.059	.063	.0528	.0548	.002583
17	.0453	.049	.053	.057	.0473	.0493	.002048
18	.0408	.044	.048	.052	.0428	.0443	.001624
19	.0359	.040	.044	.047	.0379	.0399	.001288
20	.0320	.036	.040	.044	.0340	.0360	.001022
21	.0285	.032	.036	.040	.0305	.0325	.0008101
22	.0253	.029	.033	.037	.0273	.0293	.0006424
23	.0226	.027	.031	.035	.0246	.0266	.0005095
24	.0201	.024	.028	.032	.0221	.0241	.0004040
25	.0179	.022	.026	.030	.0199	.0219	.0003204
26	.0159	.020	.024		.0179	.0199	.0002541
27	.0142	.018	.022		.0162	.0182	.0002015
28	.0126	.017	.021		.0146	.0166	.0001598
29	.0113	.015	.019		.0138	.0158	.0001267
30	.0100	.014	.018		.0120	.0140	.0001005
31	.00893	.0124			.0109	.0129	.0000797
32	.00795	.0115			.00995	.0120	.00006321
33	.00708	.0105			.00908	.0111	.00005013
34	.00631	.0098			.00831	.01031	.00003975
35	.00562	.0086			.00762	.00962	.00003152
36	.00500	.0080			.00700	.00900	.00002500
37	.00445	.0075			.00645	.00845	.00001983
38	.00397				.00597	.00797	.00001572
39	.00353				.00553	.00753	.00001247
40	.00315				.00515	.00715	.000009888

The size of wire and the number of

ampere-turns is now known. If the current is known then the number of turns can be readily calculated by dividing the ampere-turns by the current. The number of turns and the size wire being known, the size of the coil, that is its length and depth can be calculated. If the size of coil does not give the same mean length of one turn as used in calculating the sectional area of the wire, it may be well to go over the work up to this point, using the more correct mean length of one turn.

number of turns, gives the current that should be used. In Table I, S. C. C. stands for single, D. C. C. for double, and T. C. C. for triple cotton-covered wire, S. S. C. for single silk, and D. S. C. for double silk-covered wire.

Table II is very useful in many calculations for magnet-winding problems. It was compiled by S. S. Wheeler. If the total number of turns, the size of the wire, and the mean length of one turn have all been determined, then the resistance of

TABLE II

Data of Insulated Wire								Per cent. of Solid Copper in any Volume of Winding
No. American or B. & S. Gauge	Turns to the Inch	Layers to the Inch	Turns to the Square Inch	Feet Per Cubic Inch	Ohms Per Cubic Inch	Pounds Per Cubic Inch	Feet Per Pound	
4	4.5	4.87	22.1	1.84	.0004576	.24	7.	.75
5	5.09	5.82	29.6	2.46	.0007738	.24	9.	.74
6	5.66	6.41	36.3	3.02	.0011963	.24	11.5	.74
7	6.2	7.3	45.3	3.77	.001780	.24	14.	.73
8	7.05	8.	56.5	4.7	.0029654	.24	17.5	.73
9	7.66	8.42	64.5	5.37	.0042574	.24	22.	.73
10	8.54	9.6	82.	6.83	.00683	.238	27.	.72
11*	9.7	11.	116.7	9.72	.012254	.236	34.	.72
12	11.2	12.8	143.4	11.95	.0150654	.233	42.	.71
13*	12.	14.	168.	14.	.03627	.23	55.	.71
14	13.	15.4	200.	16.66	.0431627	.227	68.	.70
15	15.37	17.9	275.5	22.96	.071520	.224	87.	.68
16	16.74	19.4	324.7	27.06	.108757	.22	110.	.64
17	17.74	21.33	378.4	31.53	.15980	.217	140.	.62
18*	19.5	23.	448.5	37.38	.2389	.19	175.	.61
19	22.77	24.9	567.	47.25	.39165	.185	220.	.60
20	25.7	29.7	763.3	63.60	.6464	.184	280.	.58
21	28.3	32.5	920.	76.6	.98163	.182	360.	.57
22	31.	36.	1116.	93.	1.502	.18	450.	.55
23	34.4	40.36	1890.3	115.86	2.36	.178	560.	.52
24	36.9	44.6	1649.	137.4	3.53	.168	715.	.45
25	38.	47.	1790.	149.2	4.734	.145	910.	.43
26*	42.	50.5	2100.	170.	7.	.14	1165.	.41
27*	48.	55.5	2600.	210.	10.5	.135	1445.	.40
28	53.28	61.1	3256.	271.3	17.63	.13	1810.	.39
29*	59.	68.	4000.	335.	27.	.125	2280.	
30	63.26	76.8	4860.	405.	41.84	.121	2800.5	.38

* Estimated.

If the current is not known, but the sectional area of the winding space is known, approximately at least, then the total number of turns and the current may be calculated as follows: By means of a table giving the size of magnet wires over the insulation, as given in Table I, the number of turns per layer and the number of layers may be determined. The product gives the total number of turns that can be put in the given space. The ampere-turns, divided by the total

the coil can be calculated. The mean length of one turn in feet, multiplied by the total number of turns, gives the total length of wire in feet. From a wire table the resistance per foot of the size wire used can be obtained. This multiplied by the total length gives the resistance of the spool.

The coil must be designed so that the surface presented to the air will be sufficient to radiate the heat developed. The coil can radiate from ½ to 1 watt per square inch of exposed surface,

depending upon various conditions. The ends of the coil will assist materially in radiating heat, as does, also to some extent, the inner surface that lies against the iron core. The total amount of heat to be radiated may be calculated from any one of the following three formulas, in which $W =$ watts to be radiated, I the current, R the resistance of the coil, and E the difference of potential between the terminals of the coil:

$$W = I^2 R; \qquad (3)$$
$$W = E I; \qquad (4)$$
$$W = \frac{E^2}{R}. \qquad (5)$$

W divided by the area of the exposed surface of the coil in square inches will give the number of watts to be radiated per square inch. As stated above, this should not exceed from ½ to 1 watt. If it does, a larger size wire or more turns and a smaller current should be used. The temperature of the coil should not rise over 55° or 60° F. above the surrounding temperature. A useful formula, taking into account the cooling effect of at least a little of the surface between the coil and the iron core, is the following:

$$t = \frac{80\, W}{A}. \qquad (6)$$

In this formula $t =$ temperature rise in degrees Fahrenheit, $W =$ watts expended in the coil, and $A =$ outside surface only of the coil in square inches. That is, the rise in temperature of the coil is equal to 80 times the number of watts expended in the coils divided by the outside surface of the coil in square inches. It should be remembered that the shape of the coil and its position with regard to neighboring portions of the magnetic circuit, will have considerable influence in determining the number of watts that can be radiated by the surface of the coil. Coils that are in motion or in especially cool places may be allowed to radiate a greater number of watts per square inch than coils at rest or in hot and confined places. Formula 6 may be used in connection with field-magnet coils of dynamos as ordinarily constructed. For ordinary dynamo field coils the depth of winding should not exceed about 2½ inches, otherwise the inner turns may become too hot.

The dimensions of a spool to hold a given length of wire of given diameter may be determined as follows: Let $L =$ total length of wire in the coil in feet, $D =$ diameter of wire over insulation in mils, $d =$ diameter of bare wire in mils, $x =$ outside diameter of the coil in inches, $y =$ diameter of the core $=$ inside diameter of the coil in inches, and $z =$ length of the coil in inches.

Let x and y be known, or assume some value for them, then the length of the coil

$$z = \frac{.00001528\, L\, D^2}{(x^2 - y^2)}. \qquad (7)$$

Thus, if the core diameter is known, and the outside diameter is known or assumed, the length of the coil can be calculated.

If y and z are known or assumed, then the outside diameter of the coil may be calculated from the following formula:

$$x = \sqrt{\frac{D^2 L + 65{,}450\, z^2 y}{65{,}450\, z}}. \qquad (8)$$

If the dimensions of the spool are known, then the total length of wire of a given size to fill the spool may be determined by solving the last formula for L. Doing this, we obtain:

$$L = \frac{65{,}450\, (x^2 - y^2)}{D^2}. \qquad (9)$$

The volume, occupied by a given length of wire, is equal to its cross-section multiplied by its length; hence, the volume v divided by the cross-section of the wire gives the length of the

wire. If the wire is wound on a spool, the area occupied by each wire will be approximately equal to the square of the diameter and not to $\frac{\pi D^2}{4}$, because when the wires are piled over and alongside one another, each wire occupies nearly a square, each side of which is equal to the diameter of the insulated wire. To be sure, the layers embed upon one another, and it is quite customary to allow 10 to 15 per cent. for embedding. For the present the embedding will be neglected, however. The volume v divided by the square of the diameter gives the approximate total length of wire. Therefore, the total length $\frac{v}{D^2}$ in inches multiplied by $\frac{r}{12}$, which is the resistance per inch, r being the resistance per foot, as found in wire tables, gives the approximate total resistance of all the wire on the spool in feet. If the layers embed 10 per cent. the total resistance would be given by the formula:

$$R = \frac{1.1\, v \times r}{12 \times D^2}.$$

It frequently happens that all the dimensions of a spool for a magnet are known. This is generally the case when spools are to be merely rewound. If a given space is filled with a winding of insulated wire and is to be refilled with another size wire that does not differ very much, however, from the first, then the proportions that will be given presently are approximately true. The more nearly the two sizes approach one another, the more exact the proportions become. The reason the proportions are only approximate is due principally to the fact that the space occupied by the insulation is not proportional to the space occupied by the copper wire. For, although the sectional area of the wire increases as the square of its diameter, the insulation, being made no thicker, increases only as its diameter.

The resistance of two coils of exactly the same dimensions, will be approximately proportional to the squares of the number of turns of wire in each coil. That is $\frac{R}{R^1} = \frac{(n)^2}{(n)^1}$; in which R is the resistance and n the number of of turns in one coil and R^1 and n^1 the resistance and number of turns in the other coil. Furthermore, the number of turns of insulated wire that can be put in a given space will be approximately inversely proportional to the square of the diameter over the wire and its insulation. That is, $\frac{n}{n^1} = \frac{(D^1)^2}{(D)^2}$; in which D is the diameter of the wire over insulation in the coil having n turns and D^1 the diameter of the wire over insulation in the coil having n^1 turns. For, if a given spool, wound full of wire, is rewound with another wire of one-half the sectional area, the spool will contain twice the number of turns, and, therefore twice the length of wire. But the resistance per unit length of the second wire is twice that of the first, hence the spool contains twice the length of wire, each unit length of which has twice the resistance of the first. Consequently, the spool, when rewound with a wire having one-half the sectional area, will have four times the resistance of the spool as originally wound.

From the two proportions last given it can be shown that $\frac{R}{R^1} = \frac{(D^1)^4}{(D)^4}$, in which D is the diameter of the insulated wire that gives the spool a resistance of R ohms, and D^1 is the diameter of the insulated wire that gives the spool a resistance of R^1 ohms. In this case

the resistance is inversely proportional to the fourth power of the diameter of the wire.

If the ampere-turns are kept constant, then $\frac{I}{I^1} = \frac{(D)^2}{(D^1)^2}$ in which I and I^1 are the currents necessary when exactly similar sized spools are wound with insulated wires having diameters D and D^1, respectively. It can also be shown that $\frac{I}{I^1} = \frac{\sqrt{R^1}}{\sqrt{R}}$. That is, the current varies directly as the square of the diameter of the insulated wire and inversely as the square root of the resistance. As already stated, the above proportional equations are approximately true only between wires of very nearly the same size.

The diameter of a copper wire that will fill a spool of given dimensions and offer a given resistance, can be approximately determined as follows: Let d = diameter of the bare copper wire, l = length of the winding space, d_o = outside diameter of the coil, and d_i = the inside diameter of the coil; all the above being expressed in inches. Furthermore, let R = resistance of the coil in ohms. Now the total number of turns in a coil is equal to the section area of the winding space in square inches multiplied by the number of wires that can cross a square inch. Hence, the number of turns = sectional area of winding space × number of wires per square inch. The total length of wire is equal to the number of turns multiplied by the mean length of one turn. The mean length of 1 turn $= \frac{\pi}{2}(d_o + d_i)$. The sectional area of the winding space $= \frac{l(d_o - d_i)}{2}$. The number of wires per square inch $= \frac{1}{D^2}$, approximately; D being the diameter in inches of the wire over its insulation. Substituting these quantities, we get the total length of wire $= \frac{l(d_o - d_i)}{2} \times \frac{\pi(d_o + d_i)}{2} \times \frac{1}{D^2} = \frac{\pi l (d_o^2 - d_i^2)}{4 D^2}$. A mil foot of copper wire has a resistance of 10.5 ohms at 75° F., hence a copper wire 1 inch in diameter and 1 inch long will have a resistance of $\frac{10.5}{12 \times 1{,}000^2}$ ohms, and a copper wire having a diameter of d inches will have a resistance of $\frac{10.5}{12 \times 1{,}000^2 \times d^2}$ ohms per inch length. Then for the total resistance of the coil, we get

$$R = \frac{\pi l (d_o^2 - d_i^2) \times 10.5}{4 \times D^2 \times 12 \times 1{,}000^2 \times d^2}.$$

In order to reduce this to a convenient form, it is necessary to make the approximation that $D = d$. This will not produce a very serious error, and the error reduces as the wire increases in size. Making this approximation and solving for d gives

$$d = .0288 \sqrt[4]{\frac{l(d_o^2 - d_i^2)}{R}} \text{ inches.}$$

After calculating d, the size of wire that has this diameter may be obtained from most any wire table.

There is one more formula that may sometimes prove useful. Let x be the outside diameter of the coil, y the diameter of the core, l the length of the winding space between the inside edges of the spool, D the diameter of the insulated wire in mils, and T the number of turns in the coil. If all these quantities, except D, are known, then D may be calculated by the following formula:

$$D = \sqrt{\frac{500{,}000\,(x - y)\,l}{T}}.$$

ONE-PIECE COPPER COWL

WM. WEIGMAN

THE great advances made in ship building in the last few years, have resulted in many changes both in design and new methods of workmanship. Where changes in design were made, it was not only for the purpose of ornamentation, but for labor and material saving as well, and it is in this respect that the method of making the cowl or ventilator has found room for improvement over the old method. The cowls now used on ships are an essential feature, and at the same time they are one of the first fittings to be seen and are therefore one of the ornamental features of a vessel. Formerly these cowls were made of two or more pieces of copper, generally of four pieces, but as advances were made in other lines of work, the cowl followed in the same line of progress, and the one-piece cowl was brought out. It is difficult to see any room for improvement in the present method, while in the old method of making the cowl of two or more pieces a considerable amount of waste was unavoidable.

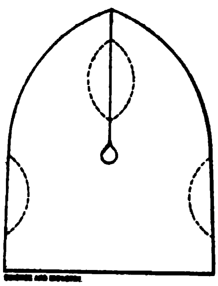


Fig. 1

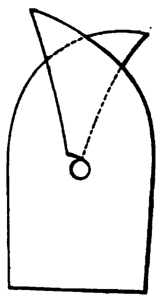


Fig. 2

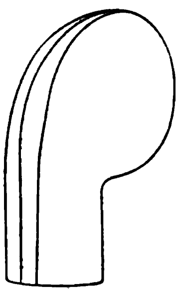


Fig. 3

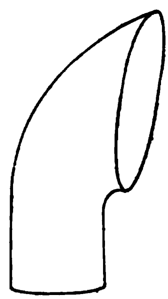


Fig. 4

Let us look first at the sheet developed for a one-piece cowl. Fig. 1 shows the sheet with only the upper corners cut. To develop this, simply take the radius given on the back of the cowl and strike it off on each side, as shown in the figure. The width of the sheet is the circumference of the base of the cowl, and the line in the center shows where it will have to be cut. This line will make the mouth of the cowl, which will be seen later on. The length of this line is found by finding the circumference of the mouth less $2\frac{1}{2}$ inches for every foot, to allow for stretching. This line must not be cut until it is first worked where the dotted lines are shown in the center. This space must be worked on a hollow block, and then cut on the center line. This is done so that an overhang can be obtained. The required overhang for an elliptical ventilator is one-third the vertical diameter, but this is not all that is necessary to get the overhang. Both sides on the lower end of the sheet where the dotted lines are shown, must also be raised and then all three places, the center and two lower ends on the opposite sides of the sheet, must be beaten back again on some plane surface. This will bring the copper to the shape shown in Fig. 2. It is plainly seen that the copper has overlapped itself and has risen in the center. The more this rises in the center the better it is, because this part of the sheet forms the throat, or lower end of the mouth, and the sheet should

overlap itself 2 inches for every inch of overhang that may be required. The sheet is now ready to be bent backwards into the shape shown in Fig. 3. The coppersmith has now only to make his seam, which is seen to be on the back, ready to braze, and then with a small mallet, shape the cowl to a pleasing shape or to the radius given on the back. This is where the labor-saving is accomplished by only having to get ready, braze, and hammer one seam; whereas to make a cowl of more than one piece would require more time in this one particular alone. We now have the cowl ready for its finishing touches. The coppersmith can now planish the cowl and when finished, it will be as shown in Fig. 4. All that remains, is to put a brass or copper bead of pipe on the edge of the mouth and the cowl is finished.

IMPROVEMENT IN PIG-IRON CASTING

WM. GILBERT IRWIN

ONE of the most important innovations in pig-iron making introduced in recent years consists of the patent iron-casting and conveying apparatus which has been in use for some time at the Lucy Furnaces, in Pittsburg, and has recently been introduced at different other plants. This new apparatus involves no new principles or complicated machinery. In fact, the idea is an old one, and probably many furnacemen were tempted to put it into practice long ago. At the Lucy Furnace plant there are two machines, a carrier and a conveyor, both horizontal and running at right angles to each other. The carrier consists of two parallel chain belts, each equipped with 200 molds. As the molds pass under the spouts of the pouring pots the iron flows into them in turn. The carrier moves 15 feet per minute, and as its speed is uniform, the size of the pig depends upon the flow of the metal while the mold is passing under the spout. The distance traveled by the molds is 85 feet, which allows time for the pig to cool sufficiently to prevent bleeding. At the end of a journey it falls upon the flat surface of the conveyor. Cooling is hastened by dropping water on the pigs as they travel, and by an ingenious shield the hot sides of the mold are protected from contact with the water. The passing of the chain over the sprocket is usually enough to cause the pigs to fall from the mold of their own accord.

The molds have furnished the chief impediment to making the scheme altogether practicable. Those now in use are made of iron, and are cast directly from the product of the furnace, and their value as pig iron is in no way impaired by being used as molds. They can therefore be turned into pigs when cracked or otherwise rendered useless. The mold is 24 inches long, 10 inches wide at the top, and about 5 inches deep. The weight of the new molds averages about 200 pounds. The device by which the cracking is to a great degree prevented is packed under the carrier, and consists of a box in which, on its return trip, each mold is dusted with lime. The lime also prevents the sticking of the pigs in the mold. An attendant stationed underneath repairs the cracks in the molds with loam. The life of a mold is about 27 days, and the cost of their manufacture is very small.

The conveyor, or second machine,

consists of 650 one-eighth inch plates, 12 by 36 inches, moved by a continuous chain and at right angles to the carrier. Most of the journey of 308 feet is in a steel tank, 4 feet wide by 3 feet deep, filled with water. Toward the end of the journey the pigs issue from the water, are elevated at an angle of about 30°, and fall into a car. The journey from ladle to car is accomplished in 11 minutes. The car stands on scales and is moved by an attendant at will by means of a turning capstan. The capstan is propelled by a shaft from a 10 H. P. engine, which furnishes motive power for the entire apparatus.

The casting house at the Lucy Furnaces is located some distance from the banks of the Allegheny River, and the metal when drawn from the furnaces is carried by rail to the casting house in 15-ton ladles on specially constructed trucks built at the Keystone Bridge Works of the American Bridge Company. These ladles are of ordinary type, and are tipped for pouring by a series of geared wheels manned by a single workman. Seven to ten ladles are required for a cast of both furnaces at the plant, and the metal has been found to be in good condition for casting after having remained in the ladles for two hours. The pouring pot which receives the melted metal from the ladles and delivers it to the molds is of simple design and is lined with firebrick and grouted between casts with ordinary fireclay. The most striking advantage of the new machine is the great reduction in the cost of labor. Another advantage lies in the fact that it is almost sandless. Under the old method the metal is run out of the furnace into sand molds, and in order to make it possible for the workmen to work about the molding bed while the metal was cooling, it was necessary to cover the hot mass with a heavy bed of sand. The new process is known as the Uehling process, and the cost of installing a machine capable of caring for 800 tons of metal in 24 hours is about $6,000. Single and double-strand machines of this type are now in operation in different furnace plants in this district and are giving entire satisfaction.

A COMMON QUESTION

DID you ever run across the man who likes to encourage the electrical engineer by telling him that "electricity is in its infancy?" If so, you will likely have noticed that after talking to you for a while he usually winds up about as follows: "Yes, my friend, all these things are very wonderful, but can you tell me just what electricity is?" He asks this question in a way that shows full well that he does not expect an answer, and chuckles to himself at the way he has cornered you. Here is a man, he thinks, whose business it is to work with something and he can't tell what it is. He looks upon this as a good joke on you in particular, and the electrical fraternity in general.

Now, as a matter of fact, if you adopted the Irishman's method of answering a question by asking another, the other fellow might find himself badly stuck. Suppose you ask for an explanation as to what light is or what heat is. He will doubtless begin to tell you all about wave theorys, wave lengths, and a lot of other things, but after all he can only tell you what light and heat are *thought* to be. There are also several theories as to what electricity is and you are,

therefore, just as well off regarding a knowledge of electricity as he is of light or heat. What we know of electricity is the result of experiment. We have a great many experimental facts at our disposal, and on these facts as a groundwork, a theory as to what electricity is can be built up. The theory which will give a satisfactory explanation of the greatest number of experimental facts is accepted for the time being, but may be modified later. Later experiments may bring out points that show the old theory to be untenable and a new one has to be constructed. It is the same way with regard to the theory of light, heat, sound, or other physical phenomena, and the man who thinks he is sticking you by asking you to explain just what electricity is, and who thinks he has a good joke on you when you can't explain, is likely to be pulled up short when you ask him to tell you the exact nature of a few other common physical phenomena.

As stated above, we first get the experimental facts and then construct a theory that will fit the facts. In other words, we state what we *think* electricity is. We know that when a wire is moved across a magnetic field, an E. M. F. is set up in it. This experimental fact was discovered by Faraday. We know that such is the case. Just why it is the case and just how this E. M. F. is set up we do not know, although we may construct a theory which will set forth what we believe to be the case. Copper conducts electricity much better than iron, and it also conducts heat better than iron. These are facts, and the best we can do is to construct theories which will explain these facts to the best of our knowledge.

Now, as far as the use of electricity is concerned, it makes very little difference whether we know what electricity is or not. We know how to generate it and utilize it, and we also know very exactly the laws governing its flow, how it acts under given conditions, and so on. Some men seem to get the idea into their heads that they cannot learn anything about electricity unless they first know just what electricity is. The desire to get to the bottom of things is a praiseworthy one, and every person interested in electrical work should be familiar with the latest theories and ideas regarding the nature of electricity, but a knowledge of such theories is not essential to a man's understanding the practical applications of electricity. Dr. Oliver Lodge's book, "Modern Views of Electricity," is an excellent source of information regarding the various theories regarding electricity. An exceptionally clear article on this subject, by Prof. Fleming, appeared in the May, 1902, number of The Popular Science Monthly. Theories regarding the nature of electricity have changed greatly within the last few years, but this has not interfered with its practical applications.

The man who gets into a stew and makes up his mind that he can't learn anything about electricity until he finds out just what electricity is had better leave theories alone for the time being, and take the experimental facts as he finds them. If he does this he will be surprised to find that he is learning a great deal about the subject, and if he attends strictly to business the chances are he will know so much, or think he does, that he will get up a pet theory of his own. At any rate, it is to be hoped he will. He will then be ready for those cheerful people who take a delight in asking for information on the subject. A dose or two of his pet theory would, no doubt, cure them of the habit.

A column of water 1 foot in height gives a pressure of 0.433 pound per square inch at the base. A water column in a mine 1,000 feet deep gives a pressure of 433 pounds per square inch at the pump, when the water is not flowing.

Condensing engines require from twenty to thirty times the amount of the boiler feedwater, for condensing purposes. An approximation, for estimating purposes, is $1\frac{1}{4}$ gallons condensing water per minute per indicated horsepower. It is usually estimated that a condenser will decrease the fuel consumption by from 20 to 25 per cent.

The American standard boiler horsepower as adopted is: Thirty pounds of water evaporated per hour at a boiler pressure of 70 pounds, the temperature of the feedwater being 100° Fahrenheit. For example, a boiler evaporates 300 pounds of water per hour, boiler pressure 70 pounds, feedwater 100° Fahrenheit, then the boiler would be $300 \div 30 = 10$ horsepower.

A $1\frac{1}{8}$-inch round steel rope, weighing 2 pounds per foot and with a breaking strain of 84,000 pounds, should sustain itself with a length of 42,000 feet before breaking from its own weight. Taking the usual factor of safety of 7, then the safe working length of such a rope would be 6,000 feet. If a weight of 3 tons is hung on the rope, equivalent to a loaded cage, the maximum length at which such a rope could be used, with a factor of safety of 7, would only be 3,000 feet.

The horsepower, the quantity of work required to raise 33,000 pounds 1 foot in one minute, denoted by the symbol H. P., is referred to now as the mechanical horsepower, with a symbol written M. H. P., to distinguish it from the electrical horsepower, or kilowatt, for which the symbols E. H. P. and K. W. are employed. The electrical horsepower is a mechanical horsepower multiplied by 1.34048. Electric generators are estimated in kilowatt units and electric motors in M. H. P. units.

It is quite possible to figure out, by simple arithmetic, the power required to hoist a load up an inclined plane. The first thing to find out is the load on the engine. Take an inclined shaft, for example, 200 feet long and with a vertical depth of 150 feet. Then multiply the weight of ore, car, and rope in pounds, by the depth of the shaft in feet, and divide by the length. Say the weight was 2,000 pounds. Then $2{,}000 \times 150 = 300{,}000$; then 300,000 divided by $200 = 1{,}500$ pounds, the weight on the engine. The horsepower is found by multiplying the weight in pounds by the speed of hoisting in feet per minute and dividing by 33,000. Suppose the load is lifted at 200 feet per minute in the example already given; then $1{,}500 \times 200 = 300{,}000$; then divide by $33{,}000 = 9.1$ horsepower. To allow for friction, etc., add one-third, which brings up the power required to 12 horsepower.

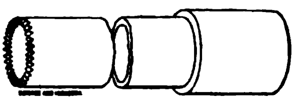
In the French coinage the metric system is directly connected with the money system. Some people are apt to speak of the United States coinage as being metric, but of course it is nothing of the sort. It is a decimal system only. The French money, besides being decimal, is directly connected with the metric system, inasmuch as the franc weighs just 5 grammes. The convenience is obvious. It would require but little change to convert the United States coinage into the metric system by making the dollar weigh 25 grammes instead of 26.729 grammes, which is the present weight. When the metric system is finally adopted no doubt the coinage will also be adapted to that system.

USEFUL IDEAS

A SIMPLE BRICK DRILL

C. G. Taylor

Having occasion to drill a number of holes quickly in some brick walls, I made use of the drill shown in the accompanying cut, it being simply a piece of ordinary iron pipe with a coupling on



one end (so as to give a larger surface on which to hammer) and teeth filed on the other. It cuts quickly, is very cheap, and unless the bricks are exceedingly hard, will drill a number of holes without getting dull.

MECHANICAL STIRRING ROD

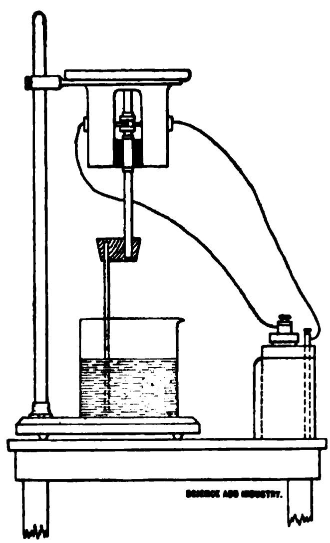
T. H. Reardon

One of the most useful things about a laboratory is a mechanical stirring rod. The accompanying sketch shows how this apparatus may be obtained with a small amount of labor and a cash outlay of about one dollar. The prime mover in this particular case consists of an electric top known to dealers in toys as the K. & D. No. 16, and costs with one cell of dry battery inclusive, $1.00. The top is inverted and its smaller end is dropped through the ring of a retort stand which serves for a support. A two-hole rubber stopper serves for a coupling, the end of the motor shaft being inserted in one hole, while the other hole receives the end of the glass stirring rod. This arrangement gives a crank motion to the rod. Of course, if a greater movement is desired the rod may be bent.

The stirring is faultless, there being absolutely no spattering or loss of solution, while the reagent is mixed with the solution in the most thorough manner and at once. In titrating volumes of liquid with standard solutions, the operator has nothing to do but note the effect of the reagent. In precipitating barium or sulphuric acid as sulphate, it has been found that the precipitate will subside almost completely in a few minutes.

In the precipitation of magnesium or phosphoric acid, where the stirring rod must not come in contact with the beaker, mechanical stirring will be found to possess distinct advantages, as there is no danger of the rod touching the sides or bottom of the beaker.

The motor described above has a two



segment commutator and when at rest it always leaves the circuit open, so there is no waste of battery power when the motor is not in operation.

BUSINESS NOTICES

The fifth annual session of the International Mining Congress will be held at Butte, Mont., from September 1st to 5th, inclusive. The advantages of holding the session in such a mining center as Butte are sure to be apparent to all those who attend.

Capt. Orlan Clyde Cullen, of Washington, D. C., has recently invented a ball-bearing rifle gun which promises to be an important factor in future warfare. The chief advantage claimed for the weapon is that the ball-bearing grooves give a rotary motion to a smooth-walled projectile, something that has long been sought for by ordnance experts. A company has been recently formed for the purpose of manufacturing the weapon, with a capital of $500,000, incorporated under the laws of the District of Columbia.

Mr. Frank Wright, mayor of Cave Springs, Ga., has recently invented an ingenious device for getting flys out of a room. It consists of a bar of thin metal, stamped to a certain form, and attached to the upper cross-bar of an ordinary screen. It is so adjusted that it leaves small openings at the top, through which the flys crawl and escape. It is said to be a fly's nature, when it lights on a screen, to crawl upwards. They never enter a room through the holes, and it is claimed that the device will clear a room of flys in a short time.

The Stephenson Manufacturing Co., of Albany, N. Y., manufacturers of Stephenson's Bar Belt Dressing, is doing a large business. On the face of an order, which they recently received from the American Cereal Co., was written, "Same as we had before and rush."

We are in receipt of a copy of the Individual Advertising Department, published by the Whitman Co., of New York. This is quite the most attractively gotten up thing of its kind we have ever seen, besides which it contains many valuable pointers, and a wealth of sound advice for every advertising man in the country.

We have received a neat little booklet of 35 pages issued by Oscar A. Michel, solicitor of American and foreign patents, 229 Broadway, New York. It is neatly gotten up and gives considerable information in regard to obtaining, selling, and protecting patents.

The Armstrong Bros. Tool Co. have entirely recovered from the serious fire which they recently experienced, and have completed the re-equipment of their plant. They have largely increased their facilities, and are now in better shape than ever before to take care of their rapidly increasing business. An ample equipment of up-to-date machinery covering 30,000 square feet of floor space is now devoted to the manufacture of Armstrong tool holders.

The new hotel Astor, one of the most magnificent hotels in the country, now being erected in New York City, is being painted with Dixon's silica-graphite paint, manufactured by the Joseph Dixon Crucible Co , Jersey City, N. J.

Ordinary watch works may generally be made effective timekeepers by careful and strong casing. The finest grades of watch works require very strong casing to protect their delicate mechanism. The best of all cases for either class is the Jas. Boss Stiffened Gold Watch Case. This is a gold case stiffened in the center with a plate of hard metal to prevent it getting thin and weak and bending down on the works, as a gold case does after a few years' wear. The outside plate of gold is very heavy, much more than is ever worn from a solid gold case and much more than can be worn off in a third of a century's hard service. In fact this outside plate of gold is a quarter of an inch thick when the process of rolling down commences. At any rate, the Jas. Boss case is guaranteed 25 years, and none was ever known to wear out. The styles of the Jas. Boss case are very elegant—the same as the finest solid gold cases—beautifully hand carved, superbly finished—very thin or very massive, as fancy may dictate—and in all sizes, for men and women's wear. The price is much lower than that asked for a solid gold case—the reason is that the Jas. Boss case saves you paying for gold that is never seen and never used. Jewelers everywhere keep a full stock of these elegant cases—they have sold more than 7,000,000 of them in the last 35 years. Ask your dealer to see them; or for the book showing why a Jas. Boss Stiffened Gold Case is better than a solid gold case, write to the Keystone Watch Case Co., Philadelphia.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

MECHANICAL

If Walter De Greot, Brooklyn, N. Y., will send us his local address we would like to communicate with him in regard to the inquiry he recently sent in.

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(231) What are the data required and formula used for working out the efficiency of a pump for raising sand aboard a ship? Does the lowering of the vessel as she fills enter into the problem? Please assume data and solve an example.

R. M. B., Brooklyn, N. Y.

ANS.—The efficiency of a centrifugal pump is usually taken as the ratio of the work done in raising the mingled sand and water to the indicated horsepower of the engine. This is not the full efficiency of the pump, but that of the combined pump and engine since no account is taken of the frictional horsepower of the engine. It is necessary to know the volume of mingled sand and water handled per minute, and the percentage of sand in the mixture in order to get its weight. The height of the discharge orifice above the bed of the river, the depth of the river, and the indicated horsepower of the engine must also be known. Assume that a given pump handles 1,000 cubic feet of mingled sand and water per minute, and that 40 per cent. of the mixture is sand. The height of the discharge outlet above the bed of the river is 30 feet and the depth of the river is 20 feet. The engine develops 100 horsepower. Find the efficiency of the pump. Since 40 per cent. of the mixture is sand, there will be 400 cubic feet of sand raised and 600 cubic feet of water. The work done in raising the water is $62\frac{1}{2} \times 600 \times 10 = 375{,}000$ ft.-lb. If the weight of a cubic foot of sand is 100 pounds, its weight in water would be $100 - 62\frac{1}{2} = 37\frac{1}{2}$ lb. The work performed in raising the sand to the surface of the water would be: $37\frac{1}{2} \times 400 \times 20 = 600{,}000$ ft.-lb. The work performed in raising the sand to the discharge outlet would be $100 \times 400 \times 10 = 400{,}000$ ft.-lb. The total work is, therefore, $375{,}000 + 600{,}000 + 400{,}000 = 1{,}375{,}000$ ft.-lb. $= 41\frac{2}{3}$ horsepower. The efficiency of the pump is, therefore, $41.67 \div 100 = 41.67$ per cent. Ans. The amount the ship lowers as it fills would affect the efficiency very little, since the decrease in the amount of work done is followed by a decrease in the indicated horsepower. There is, however, a slight change in the efficiency of the pump.

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(232) Which is best in a drop-flue marine boiler, a high or low crown sheet for burning hard coal? Which is best for burning soft coal? Give the reason for your answer.

M. D., Athens, N. Y.

ANS.—With dry anthracite coal, since it burns without much flame, either a high or a low crown sheet will answer equally as well. The impression that hard coal requires a low crown sheet for greatest economy is erroneous, because all the heat that is generated must be utilized either by the boiler in making steam, or by the chimney in producing draft. With bituminous coal, the case is wholly different and there is a great loss if it is attempted to burn it in a furnace having a low crown sheet. The hydrocarbon gases, which are driven off by the heat, burn with a long flame, and if this flame impinges on the boiler plates, before combustion is complete, the gases are cooled below the point of ignition and escape up the chimney unconsumed. Experiment shows that the temperature of ignition of the gases of distillation of soft coal is approximately 1,200° F., while the temperature of the furnace plates on the fire side is only about 500° F. That loss of fuel is caused by the flame striking the cooler iron, may be very readily tested by holding an iron bar in the flame of an ordinary gas jet and noting the immediate production of smoke.

(233) I have a second-motion double hoisting engine, 11″ × 14″ cylinders, $\frac{1}{6}$ cut-off; ratio of gearing, 6 to 1; diameter of drum, 20 inches. The engine is required to raise a certain load 20 feet four times a minute. The hoisting cable is geared 3 to 1. What size of boiler, of the locomotive type, is required, and what is the probable water and coal consumption per hour?

W. H. W., Toledo, Ohio.

ANS.—By use of the formula

$$M. E. P. = p_1 \frac{1 + \text{hyp. log } r}{r} - p_0,$$

where p_1 is the absolute boiler pressure, p_0 is the absolute back pressure, and r is the ratio of expansion, we find that the M. E. P. is approximately 91 pounds. The number of revolutions is found to be 275. The horsepower of each engine is found by the formula

$$I. H. P. = \frac{p\,l\,a\,n}{33{,}000},$$

where p is the mean effective pressure, l is the length of stroke in feet, a is the area of the piston in square inches, and n is the number of strokes per minute. By substitution, we find the horsepower of both engines to be 168. The water consumption of engines of this type is about 35 pounds per horsepower, therefore the total water consumption would be about 5,880 pounds per hour. On the basis of an evaporation of 7 pounds of water per pound of coal, this would give a coal consumption of 840 pounds per hour. This would require a boiler with a grate area of about 40 square feet and a heating surface of about 1,700 square feet.

***

(234) What horsepower gasoline engine will it require to run a dynamo having a capacity of 100 16-candlepower lights. Actual brake horsepower is meant, not nominal or indicated.

I. L. E., Memphis, Tenn.

ANS.—The engine would have to deliver about 10 brake horsepower. The actual amount of power required to run the lamps would be about 8 horsepower, but in order to allow for losses in the lines and dynamo, and also in belt friction, it would not be advisable to install an engine smaller than 10 H P.

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(235) (a) Please give me the names and prices of some of the latest books for a young apprentice commencing his term in a machine shop, and who wishes to become a mechanical engineer. Do you recommend the following two books as suitable for a young apprentice: "Extracts From Chordal's Letters," "Machine Shop Arithmetic," by Colvin?

A. J. T., Wellington, B. C.

ANS.—The books which you mention are both good in their line, but do not by any means cover the whole ground of mechanical engineering. If you are working in a machine shop and wish to become a mechanical engineer, we should strongly advise you to take a course in the International Correspondence Schools in mechanical engineering. This will give you a much more thorough grounding in the profession than you can obtain in any other way, while you are working.

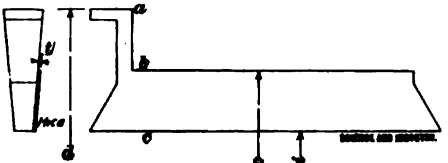
ELECTRICAL

(236) (a) Why do most electric-lighting stations use an alternating current? (b) Can the voltage of an alternating current be found with an ordinary voltmeter? (c) Can an alternating current be used to run an electric motor, made for a battery current, when put in series with one or more lamps? (d) How can the frequency of an alternating current be found? (e) How is the swing of a lathe measured? (f) Is a one-quarter horsepower gas engine of any practical use? A. B., Bellevue, Pa.

ANS.—(a) So that a high pressure may be used for transmitting the current and thus allow lights to be supplied over a large area with comparatively small loss. Alternating current can be readily transformed from high to low voltage whereas direct current cannot. Also, it is not easy to generate direct current at high voltage because of trouble at the commutator. (b) This depends upon how the voltmeter is constructed. Some voltmeters will indicate on either alternating or direct current, but in most cases if the instrument is calibrated with direct current it will not indicate correctly if used on alternating current. Voltmeters of the hot-wire type can be used equally well on either direct or alternating current. (c) No. (d) By counting the number of poles on the alternator and measuring the speed of the alternator with a speed counter. If n is the frequency in cycles per second, P the number of poles, and S the speed in revolutions per minute, then $n = \frac{P}{2} \times \frac{S}{60}$. For example, the frequency of an 8-pole alternator running 900 revolutions per minute is $n = \frac{8}{2} \times \frac{900}{60} = 60$ cycles per second. (e) By measuring the distance from the lathe center to the nearest point of the ways and doubling this distance. In other words, the swing is the largest diameter that can be turned in the lathe. A 16-inch swing lathe is one that will take an object 16 inches in diameter. (f) Yes; if the engine is well built. An engine of this size would run light machine tools.

(237) (*a*) Give a rule for finding the thickness of commutator segments at the points *a*, *b*, and *c*. (*b*) Should the calculations be made for the diameters with the mica in and deducting the thickness of the mica from each thickness for the bar or pattern? H. C., Paterson, N. J.

ANS.—(*a*) and (*b*) Let d_o be the diameter of the face of the commutator with mica in place, and let d_i be the inside diameter.



The outside circumference or face of the commutator will be $3.1416 \times d_o$, and the inside circumference $3.1416 \times d_i$. Let t be the thickness of mica (expressed in decimals of an inch) and n the number of segments. then $n \times t$ is the number of inches of circumference occupied by mica, and $3.1416 \times d_o - nt$ is the number of inches of outer circumference occupied by the bars. Hence the width of each bar at the circumference is $b = \frac{3.1416 \times d_o - nt}{n}$. The sides of the mica are parallel, hence nt is also the space occupied by the mica on the inner circumference, and the width $c = \frac{3.1416 \times d_i - nt}{n}$. The width at $a = \frac{3.1416 \times d - nt}{n}$. For example, suppose the face of a 50-bar commutator is 6 inches in diameter and the mica is .030 inch thick. The inside diameter is 4 inches. What are the dimensions *b* and *c*. We have $b = \frac{3.1416 \times 6 - 50 \times .030}{50} = .347$ inch nearly.

The width at $c = \frac{3.1416 \times 4 - 50 \times .030}{50} = .221$ inch.

***

(238) The Interurban Railroad running through here gets its power from Allegan, 40 miles distant. Here they have three transformers and a large rotary converter. (*a*) What is the office of these transformers? (*b*) Why not connect the power from Allegan direct to the trolley? (*c*) What is the office of the converter? (*d*) Does the power come in irregular pressures to the transformers and do they equalize the pressure to the trolley? W. C. H., Augusta, Mich.

ANS.—(*a*) In order to transmit the power over the long distance a high pressure has to be used, and the function of the transformers is to step-down or lower the line pressure to an amount suitable for the rotary converters. (*b*) Because the pressure would be far too high and also because the line current is alternating and a direct current is required for operating the cars. (*c*) To change the alternating current to direct current after the pressure has been lowered by the transformers. Direct current is better suited to the operation of the cars than alternating current. (*d*) The transformers do not equalize the pressure, as no such equalizing is necessary. They take a comparatively small line current at high pressure and transform it to a current of large volume at low pressure.

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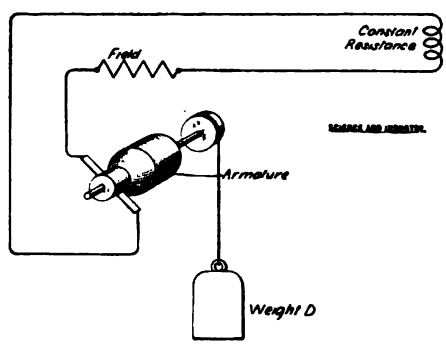
(239) The accompanying sketch shows a series-dynamo used as a brake, the power being dissipated by a resistance. The action is continuous, that is, weight *D* falls indefinitely. What effect will a change in weight have upon the speed of fall, other conditions being the same in both cases?

O. C. R., Pittsburg, Pa.

ANS.—An increase in weight would cause an increase in speed though the amount of increase would be quite small unless the fields of the series-dynamo were saturated. Neglecting losses, the power developed by the moving weight must be equal to the power delivered by the dynamo. When the weight is increased, the driving torque is also increased, and there must be an increase in the current generated. Since the resistance is fixed, the E. M. F. must increase. However, the increased current passes around the field; hence, if the iron is not saturated, quite a small increase in speed may be sufficient to raise the E. M. F.,



because the field is strengthened at the same time that the current is increased.

***

(240) An electromagnet wound to 100 ohms performs its work at a minimum of 62 milliamperes. It is desired to know what current would be necessary at any other resistance; the depth of wire is to be always the same, or, at least, not greater than that of the original 100-ohm coil.

H. A. W., Swissvale, Pa.

ANS.—It is hardly possible to give a simple formula for this because of the fact that the percentage of space occupied by the insula-

tion on the wire increases as the size of wire is decreased. In order that the coil shall do its work, the same number of ampere-turns must be obtained no matter what the resistance may be. For example, in this case the resistance is 100 ohms and the current .062 ampere. Suppose the coil were wound with twice as many turns of the wire having half the cross-section. The resistance would then be four times as great, and the winding space would be a little greater owing to the increased space taken up by insulation. The necessary current would be half as great as before because there are twice as many turns. The current required would be in inverse proportion to the square root of the resistance. For example, if the magnetizing current at 100 ohms is .062, then at 200 ohms it would be $\sqrt{\frac{100}{200}} \times .062$, at 150 ohms $\sqrt{\frac{100}{150}} \times .062$, etc. This assumes that as the cross-section of the wire is decreased, the number of turns in the available space is increased in like proportion. This would not be exactly the case because of the greater amount of space occupied by insulation when the smaller wire is used. You will find a great many formulas relating to electromagnets in a book called "The Electromagnet," published by The Varley Duplex Magnet Co., Phillipsdale, R. I. These formulas indicate the allowance to be made for insulation, etc.

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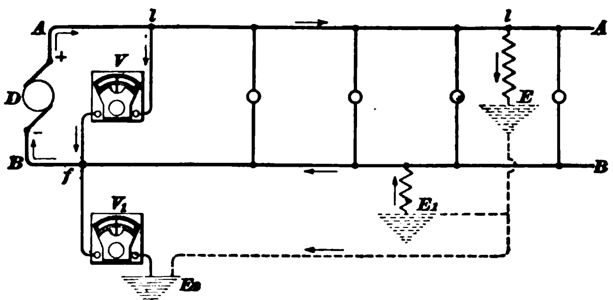
(241) What is the best formula to use in finding the insulation resistance of a circuit?
I. I. D. Cebu, Philippine Islands.

Ans.—The best formula or method of test depends upon the kind of test that is to be made, and no one formula or method can be laid down as the best in all cases. One of the most convenient methods of measuring insulation resistance, is by means of a high-resistance voltmeter of Weston or similar



type. Suppose in the accompanying figure the resistance of line $A\,A$ is to be measured, the voltmeter is first connected as shown at V; call this reading V. It is then connected as at V_1, one terminal being connected to line $B\,B$ at f and the other to ground; call this reading V_1. If r is the resistance of the voltmeter, then $R = \frac{(V - V_1)\,r}{V_1}$ where R is the insulation resistance. This test should be made for both sides of the circuit.

***

(242) (*a*) How can a carbon button be secured to a brass block, as in the solid-back transmitter? (*b*) Is there a cement of good electrical conductivity that will hold carbon to a metal, such as brass or aluminum? (*c*) How can carbon electrodes, such as those used in solid-back transmitters, be highly polished. A. G., East Clifton, P. O.

Ans.—(*a*) By electroplating with copper the surface of the carbon button that fits against the brass block, and then soldering the carbon and brass pieces together. Very often the carbon button is secured to the brass block by a machine screw that passes through the carbon into a thread in the brass block, the head of the screw being countersunk in the carbon button. (*b*) We do not know of any that would be sufficiently strong. (*c*) The method of polishing carbon buttons is more or less of a trade secret. They can probably be polished on a fine emery wheel or by the use of grindstone dust.

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(243) We have an evaporator with two kilns 20′ × 20′ supplied with hot-air heaters. (*a*) Would it be as cheap or cheaper to use electricity for evaporating? We would have to install our own plant. (*b*) If so, which is best, direct or alternating current, and at what voltage? (*c*) What would be the size of wire, current, etc. required for the heaters to heat the kilns to 175 degrees when loaded with apples? W. L. G., Middleport, Ky.

Ans.—(*a*), (*b*), and (*c*) It would be very much more expensive than hot air unless you could generate the current very cheaply by means of water-power. You do not get more than 10 or 12 per cent. of the heat value of the fuel in the shape of heat from an electric heater because of the large heat losses in the steam boiler, steam engine, and also to a less extent in the dynamo. It is much more economical therefore to use the heat direct from the fuel. If electricity were used, direct current would be the better if the plant were located near by. If the current had to be transmitted a considerable distance, alternating current would be more economical. You have not given sufficient data on which to base an estimate of the size of heaters required. In fact, this is something which would have to be deter-

mined by trial, as there are so many unknown factors entering into the problem that it is difficult to form an accurate estimate.

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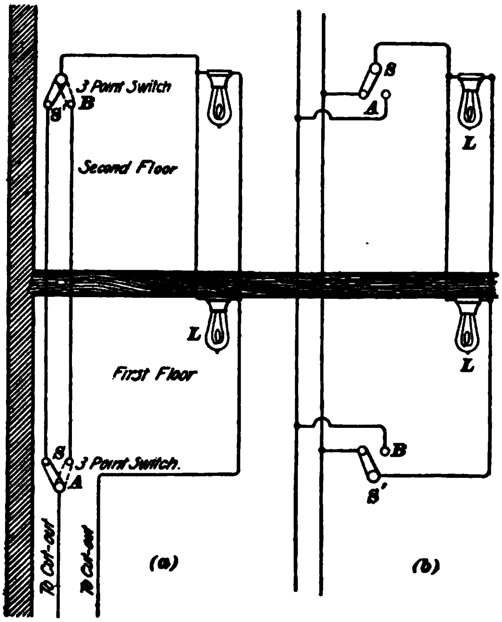
(244) (*a*) I am doing inside wiring and hear a great deal about National Fire Underwriters Rules. I have been trying to get one of these books but do not know where to send for it. Will you please tell me where I can get it and the price of it? (*b*) Please explain the wiring of a three-way switch.

E. S., Rock Island, Ill.

Ans.—(*a*) Try writing to The Underwriter's Laboratories, 67 E. 21 St., Chicago, Ill. We are not sure that any price is placed on



this pamphlet, but 10 cents should be sufficient. (*b*) The accompanying figures (*a*) and (*b*) show two methods of wiring with three-way switches. *L L* are the lamps and *S S'* the three-point switches situated at the stations *A B*. It is easily seen that the lights can be controlled from either station independently of the position of the switch at the other station.

MISCELLANEOUS

(245) (*a*) How would a galvanized steel rod protect a building from lightning if it were run from the ground up the side of the eaves, and then up the roof to the comb, and then set up in the air 2 or 3 feet? Would it be as satisfactory as the regular lightning rod? (*b*) Where can regular lightning rod be purchased?

F. J. S., Martinsburg, Ind.

Ans.—(*a*) The galvanized steel rod would probably offer a certain amount of protection to the building, but would not be as satisfactory as a regular copper lightning rod, as galvanized steel is not as good a conductor of electricity as copper. (*b*) Regular lightning rod can be purchased from E. G. Washburn & Co., 46 Cortland St., N. Y.

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(246) (*a*) What is the best composition for painting or tinting rough plastered walls? (*b*) Give me the name of a good book that treats upon this subject.

M. V. B., Los Angeles, Cal.

Ans.—(*a*) The best manner of coloring or tinting rough plastered walls is to introduce the coloring matter into the plaster. When the plaster is composed of fine gravel mixed with pure lime and hair, the several tints commonly employed may be obtained by introducing into sufficient material for 100 square yards the following ingredients: For a blue black, 5 pounds of lampblack; for buff, 5 pounds green copperas to which is added a pound of fresh cow manure mixed with the dash; a terra cotta color is obtained by using 15 pounds of metallic oxide mixed with 5 pounds of green copperas and 4 pounds of lampblack. Many tints may be obtained from these several colors by changing the quantities. The colors obtained by these proportions do not fade or change. Some of the patent plaster tints upon the market are excellent and a full description of these may be obtained by addressing Toch Bros., 468 West Broadway, New York. Should you desire merely a paint or tint for the walls, we would recommend some good water paint. Full particulars may be obtained regarding these paints by addressing Sarks, Edson & Co., Saxton's River, Vt. If an oil paint is desired, the best basis for the coloring matter is 4 pounds of white lead to 1 pint of linseed oil; sufficient coloring matter of any of the mineral pigments can be added to give the desired tint; three or four coats will be required. (*b*) We would recommend the books entitled "Modern House Painting," by E. K. Rossiter and F. A. Wright, the price of which is $5, and "Hints for Painters, Decorators, Etc.," by An Old Hand, price 25c. These books can both be secured from the Technical Supply Co., Scranton, Pa.

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(247) Please give me some information in your magazine in regard to the theoretically correct way of laying off the pattern for the elliptical cone shown in the accompanying sketch. Cones of such shape are sometimes

used in locomotives to cut out the fine cinders that collect in the boiler head after blowing through the flues.

G. A. D., Kingsland, N. J.

ANS.—The solid shown in your sketch—which we have reproduced in the plan and elevation herewith presented—is not an elliptical cone. If it were, the upper base would be defined by an ellipse whose axes would be in proportion to those of the lower base. The solid in this case is an irregular formation whose development, or lay-out, may be readily accomplished by an application of the principles known to draftsmen as triangulation. The solution is comparatively simple and consists, first, of dividing the plan into symmetrical parts by horizontal and vertical center lines. Next, the outline of both bases in one of the quadrants thus obtained is divided into a similar number of equal spaces, as shown by the letters a, c, e, g, etc. on the lower base and b, d, f, h, etc. on the upper base. Consecutive lines are next drawn through these points, as bc, cd, de, etc., and the true length of such lines is ascertained by the construction of the diagram of temporary triangles shown on the right of the illustration. The method of obtaining the true lengths of these lines by projection methods from the elevation should be understood from an inspection of the drawing. The true lengths of all lines shown in the plan and elevation having been ascertained, the pattern may be laid off. Here, the length of the line $a'' b''$ is taken from the elevation, where it is shown as the line $a' b'$; arcs are next described from a'' and b'' as centers with radii respectively equal to the distances shown on the lower and upper bases of the plan. From b'' the line bc is laid off in its true length as $b'' c''$, and the remainder of the triangles are completed in a similar manner until the points m'' and n'' are reached. The outline of the lay-out may then be defined by curves traced through a'', c'', e'', etc., and b'', d'', f'', etc., and by the straight lines $a'' b''$ and $m'' n''$. The pattern thus produced is sufficient for one-quarter of the surface of the solid shown in the projection drawings. By reversing the pattern on $a'' b''$ and on $m'' n''$ as center lines, the covering for the entire solid may be obtained.

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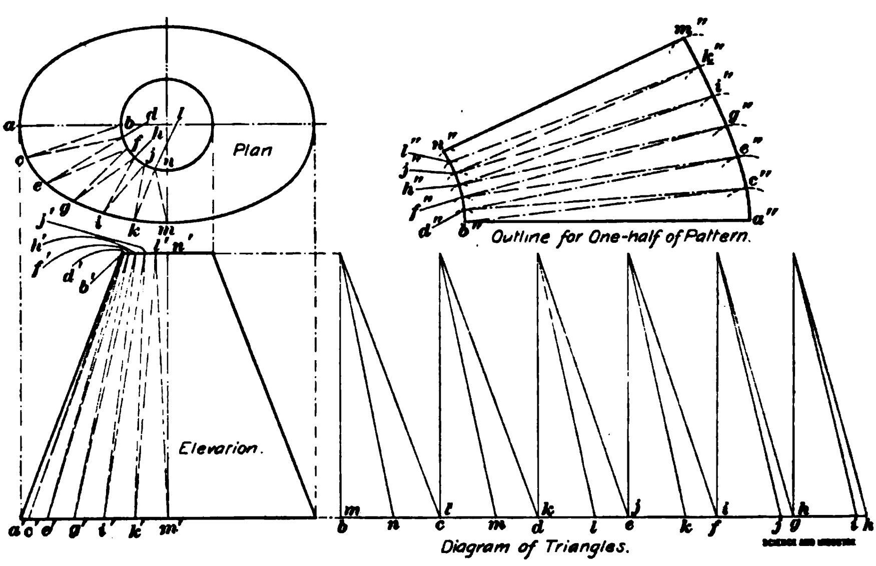

(248) (a) What is Pozzuolana cement? Where may it be bought, and what does it cost compared with Portland cement? (b) What is the method of putting zinc in boilers to prevent electrical action, and is it considered good practice?

W. T. C., McNear, Cal.

ANS.—(a) Pozzuolana cement is named after the town of Pozzuoli, in Italy, near which the ingredients were found from which it was first made. The cement is rendered hydraulic by the addition of a proper proportion of quick lime. Artificial Pozzuolana cement is made from blast furnace slag, and also from the scales from the blacksmith's forge. For information regarding where it may be purchased, and its cost, we would advise addressing Wm. Wirt Clark & Son, Builders' Exchange, Baltimore, Md. It may be possible that they can inform you of some dealer near your locality.

(*b*) It is generally understood, and has been substantiated by experiments, that zinc is a preventative of galvanic action in boilers due to the use of water containing acids—such, for instance, as salt water. It has likewise been found to be a preventative of scaling. In preventing the galvanic action the corrosion of the steel plates is lessened, for the zinc becomes the ultra-positive element as compared with the iron. The principal need to observe in placing zinc in boilers is to have a metallic contact between the iron and the zinc. The zinc can be introduced in the form of plates, and should be distributed throughout the boiler within the water space. It is not considered good practice to place it directly over plates in contact with the fire, for the oxide from the zinc dropping on these surfaces might cause over-heating. In water-tube boilers, thin narrow strips of zinc coiled around a mandrel, to form a helix, may be conveniently inserted in the tubes. As a rule, about one square inch of surface of zinc is used for every 50 pounds of water in the boiler. The zinc should be renewed every 3 or 4 months.

***

(249) Will you show me how to figure the stresses in *a b* and *b c* of the body bolster shown upon the sketch, Fig. 1; also explain how I can figure the strength of these portions. L. G. W., St. Louis, Mo.

ANS.—Referring to Fig. 2, it is assumed that there is a wooden plate or iron sill fastened at *e*, which effectually prevents bending at this point. The stresses that will then exist in the bolster are tension in *a b* and compression in *b c*, the weight upon the sills being downward at *a* and *b* and the reaction of these weights being upward at *c*. If W represents the weight upon one of the sills, then the tension in the member *a b* equals $\frac{WX}{Y}$, the distances X and Y being either in feet or inches. The compression in *b c* will equal $\frac{W\sqrt{X^2+Y^2}}{Y}$. For instance, if $W=$ 10,000 pounds and $X=40''$ and $Y=15''$, the stress in *a b* will equal by the formula $\frac{WX}{Y}$, upon substitution, $10{,}000 \times 40 \div 15 =$

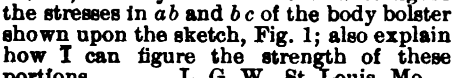

FIG. 1

26,666, while by substitution in the formula $\frac{W\sqrt{X^2+Y^2}}{Y}$, the stress in *b c* will equal $\frac{10{,}000\sqrt{40^2+15^2}}{15} = 28{,}480$ pounds. The allowable tensile strength of wrought iron per square inch of section is 12,000 pounds when a factor of safety of 4 is required; therefore, if the stress in *a b* equals 26,666, the sectional area required in this portion of the bolster will equal $26{,}666 \div 12{,}000 = 2.22$ square inches; this would require a bar $1'' \times 2\frac{1}{4}''$, and if the bar were made $1'' \times 8''$, as you have denominated in your sketch, the member *a b* would sustain $3\frac{1}{2} \times 10{,}000$ or 35,000 pounds. The strength of a compression member such as *b c*, when its length is over 10 times its

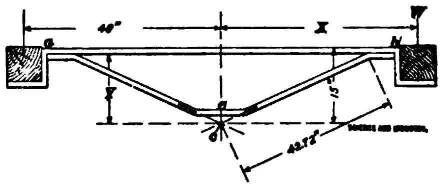

FIG. 2

least dimension, and when the ends are fixed, may be determined by the formula $S = \frac{U}{1+\left(\frac{l^2}{36{,}000\,R^2}\right)}$, in which U equals the ultimate compressive strength of the material in pounds per square inch; l equals the length of the member in inches; and R equals the least radius of gyration, while S equals the ultimate strength of the column in pounds per square inch. The value of U for structural steel is usually taken at 54,000 pounds; the theoretical length of the member *b c* equals 42.72″; the value of R^2 for any rectangular section is equal to $\frac{D}{12}$, so that if the compression member is assumed to be $1'' \times 8''$, its least radius of gyration is equal to $\frac{1}{12}$. By substituting these several values in the formula, $S = \frac{54{,}000}{1+\left(\frac{1{,}825}{36{,}000\times\frac{1}{12}}\right)}$ or 33,576 pounds. If a factor of safety of 4 is required, the safe unit compressive stress per square inch will equal $33{,}576 \div 4 = 8{,}394$, and if the brace *b c* is made of the same material as the tension piece *a b*, or $1'' \times 8''$, it will sustain $8{,}394 \times 8 = 67{,}152$ pounds. The stress to which this member is subjected, with a load W on a sill of 10,000 pounds, equals 26,666, and the load that these members, when made of $1'' \times 8''$ wrought iron, will safely sustain at W is equal to $67{,}152 \div 26{,}666$, or $2.5 \times 10{,}000$, or 25,000 pounds, these calculations showing that while the tension member, or *a b*, will sustain a load at W of 35,000 pounds, the brace, or *b c*, will only support 25,000 pounds.

***

(250) I wish some practical information regarding the methods of scaling and estimating the amount of lumber per acre of standing timber; also how to tell when a

tree is sound before cutting; how to distinguish the different species and varieties of the pine family—in fact, I want such information as will enable me to make an examination of a timber tract, and compile a reasonably accurate report as to the amount and quality of lumber it will yield.

W. B. H., Santa Fe, N. M.

ANS.—The most reliable data upon the subject you mention can be obtained from the United States Government, by addressing the United States Department of Agriculture, Chief of Division of Forestry. We would especially refer you for information relative to the estimating of standing timber, to the report of the Chief of the Division of Forestry for 1893, and would mention as an authority the book entitled "Wood Measuring," by Prof. Dr. F. V. Bauer. We would likewise suggest as interesting the pamphlet issued by the United States Government, Department of Agriculture, entitled "Forestry for Farmers," Bulletin No. 67. The United States Department of Agriculture, to our knowledge, has excellent pamphlets upon the different species of pine, their characteristics and growth, as well as physical properties. These would likewise be of interest.

***

(251) (*a*) Please tell me what India ink is composed of. (*b*) What is the composition of the colored inks generally used in drafting rooms? (*c*) What is tracing cloth composed of, and how is it made?

E. R., Pittsburg, Pa.

ANS.—(*a*) India ink consists of finely divided carbon cemented together by certain glutinous vegetable juices, gum, gelatine, etc. The precise nature of the cement or mucilage used by the Chinese in the manufacture of their inks is not known. But the greater part of the ink now sold as India ink consists of fine lampblack and glue. Purify fine lampblack by washing it with a solution of caustic soda, dry and make it into a thick paste with a weak solution of gelatine containing a few drops of musk essence, and about half as much ambergris; mould and dry. Instead of gelatine the following solution may be used: seed lac, 1 oz.; borax, ¼ oz.; water, 1 pt.; boil until solution is effected and make up with water to ¾ pt. (*b*) The materials most commonly used to color inks are as follows: Blue, 2 oz. burned umber, 1 oz. rose pink; green, 2 oz. mineral green, 3 oz. chrome green; red, 5 oz. mineral orange red, 2 oz. Chinese red. (*c*) The sizing used on drafting cloth is composed of the following materials: Boiled linseed oil, 10 pounds; lead shavings, ½ pound; zinc oxide, 2½ pounds; Venetian turpentine, ¼ pound. Boil these for several hours, then strain and dissolve in the strained composition 2½ pounds of white gum copal. Remove from the fire, and when partly cold add purified oil of turpentine in sufficient quantity to bring it to a perfect consistence. Then moisten the cloth thoroughly in benzole, and give it a flowing coat of the varnish.

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(252) (*a*) I have noticed on the roofs of barns and outbuildings upon which cupolas are built, that after a few years' exposure to the weather a large, peculiar white spot makes its appearance upon the roof of the building beneath the eaves of the roof of the cupola. Can you explain this? (*b*) Would you use a cement floor in a dairy farm? It seems to me that the surface of the floor, being rough, would have a tendency to wear away the hoofs of the cattle, making them sore.

J. F. B., Lorton Valley, Va.

ANS.—(*a*) We can offer no explanation regarding this discoloration other than that it might possibly be due to dripping of the water from the roof of the cupola. It might be interesting to construct a gutter along the eaves of the cupola to carry off the dripping from the roof of the cupola. It is possible that if this was done the discoloration would not occur. (*b*) We would think that your exception to such a floor is reasonable, and would suggest a concrete floor with an asphalt top, which is much softer, and not nearly so gritty, as a cement floor. We do not, however, feel competent to give you reliable information upon this subject, and would suggest that you address the United States Dept. of Agriculture, for their Farmers' Bulletin No. 55, entitled "The Dairy Herd, Its Formation and Management." We would also suggest that you make inquiry from the same department regarding this question as to what is the best floor for a cattle barn.

***

(253) (*a*) Give a rule for computing the center of lateral resistance of a boat before it is placed in the water. (*b*) Give a rule for proportioning the sail area of fast cat boats. (*c*) State how far back of the center of lateral resistance to place the center of effort of the sail. (*d*) What is the speed of fast cat boats? (*e*) What size engine would be required to run a 25-foot launch at a speed of 12 or 15 miles per hour? What size propeller would be required?

J. M. R., Santiago, Cuba.

ANS.—Owing to the limited space at our disposal, it is impossible to fully answer the first three questions in these columns. You will find this subject very fully discussed in the book entitled "Know Your Own Ship," by T. Walton. This volume may be obtained from the Technical Supply Co., of Scranton, Pa., for $2.50. (*d*) A well-proportioned boat with a good sailing breeze should make from 8 to 10 knots per hour. (*e*) An 80-horsepower engine would be ample to maintain

the desired speed. The propeller should have a diameter of 26 inches with a pitch of 50 inches. The propeller should make 300 revolutions per minute when running at full speed.

***

(254) Will you please explain how I must proceed in order to work out the graphical analysis of the roof truss shown in Fig. 1? What particularly worries me are the heavy loads suspended from the lower cord of the truss. A. A. H., Lawrence, Mass.

ANS.—Since the roof truss you show in your sketch is unsymmetrically loaded, it is necessary before the graphical stress diagram can be drawn to determine the forces or reactions at the supports required to equalize the loads upon the truss. The sum of these reactions is equal to the sum of the loads, but as the truss is unsymmetrically loaded they are not equal and may only be obtained by calculating the algebraic sum of the moments about either support or abutment. In order to make this calculation and in order that the stress diagram may conveniently be drawn, Fig. 2 has been laid out and the roof loads upon the rafter member assumed. In calculating the reaction at R_2 it is necessary to divide the sum of the products of all the loads and their perpendicular distances from R_1 by the span

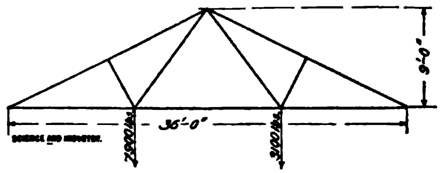

FIG. 1

of the truss. The moments of the several loads about R_1 may then be tabulated as follows:

Moment of $A\,B = 1{,}000 \times 0 \quad = \quad 0$
Moment of $B\,C = 2{,}000 \times 9 \quad = \quad 18{,}000$
Moment of $M\,Z = 7{,}900 \times 10.66 = 84{,}214$
Moment of $C\,D = 2{,}000 \times 18 \quad = 36{,}000$
Moment of $Z\,N = 3{,}100 \times 25.25 = 78{,}275$
Moment of $D\,E = 2{,}000 \times 27 \quad = 54{,}000$
Moment of $E\,F = 1{,}000 \times 36 \quad = 36{,}000$

And the sum of the moments $= 306{,}489$

The span of the truss is 36 feet, so that $306{,}489 \div 36 = 8{,}513$ pounds, which is the amount of the reaction R_2. The sum of the loads equals 19,000 and therefore the other reaction or R_1 equals $19{,}000 - 8{,}513$ or 10,484 pounds. All of the external forces acting upon the roof truss in order to maintain it in equilibrium are found and they and the accurate outline of the roof truss are shown in the diagrammatic figure or frame diagram, Fig. 2. In drawing the stress diagram shown in Fig. 3, it is first necessary to lay out the vertical load line $a\,b\,c$, etc. This line is vertical because all of the external forces upon the truss are vertical. The line is drawn by making $a\,b$, $b\,c$, $c\,d$, $d\,e$, and $e\,f$ equal by some convenient scale to the respective loads in the frame diagram, Fig. 3. When the point f has been located measure upward a distance $f\,n$ equal to the reaction R_2 or the force $F\,N$ in the frame diagram, then from n lay of $w\,z$ and $z\,m$ equal respect-

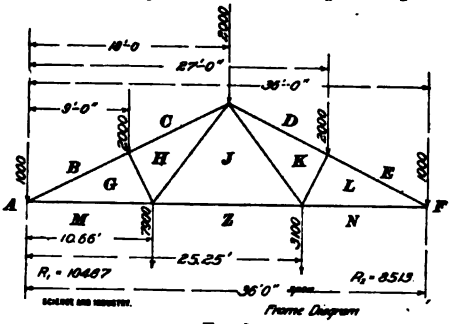

FIG. 2

ively to scale the forces similarly marked in the frame diagram and measure the distance $m\,a$ to see whether it equals 10,487 pounds, the calculated amount of the reaction R_1. If the load line does check in this way it has been correctly drawn and the polygon of external forces about the truss reads from a to b, from b to c, from c to d, from d to e, from e to f, from f upward to n, and from n downward to z, proceeding from z downward to m and going from m back to a, the starting point, and completing the polygon. After the polygon of external forces is completed in this manner, proceed to complete the stress diagram by going around the several joints in the truss as $A\,B\,G\,M$, $B\,C\,H\,G$, $G\,H\,J\,Z\,M$ in the order named. If the reactions have been cal-

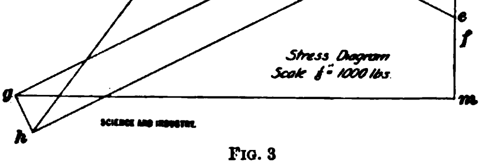

FIG. 3

culated correctly and a fair degree of accuracy used in laying out both the frame and stress diagrams, there should be no difficulty in making the figure close and securing a finished diagram complete, as

designated in Fig. 3. The diagram shown is drawn to a scale where $\frac{1}{8}$ inch equals 1,000 pounds.

***

(255) Do you know any process whereby a fine red color can be imparted to brick in the burning? C. W. L., Quebec, Can.

ANS.—The red color of brick is due to the presence of iron in the clay. Pure clay, free from iron, will burn white. The quantity of iron in the clay and the length of time the bricks are burned, together with the intensity of the heat employed in the furnace, has all to do with the color of the brick. We would advise you to consult some good work on the subject, and would recommend "Bricks, Tiles, and Terra Cotta," by Chas. T. Davis, the price of this work being $5, and obtainable through the Technical Supply Co., Scranton, Pa.

***

(256) (*a*) Please recommend a good text-book on differential and integral calculus. (*b*) Can I procure enough back numbers to fill out volumes for the years 1899, 1900 and 1901? E. J. M., Brooklyn, N. Y.

ANS.—(*a*) "Differential and Integral Calculus, by George A. Osborne, and, Differential and Integral Calculus," by P. A. Lambert, are both good books on this subject. They can both be procured from the Technical Supply Co., of Scranton, Pa. (*b*) We have most of the back numbers of SCIENCE AND INDUSTRY. If you will tell us just the numbers which you want, we can tell you whether or not we can supply you with them.

***

(257) Please answer the following questions: (*a*) What are the materials used in making sand brick? (*b*) What is their ability to stand weather and load? (*c*) What is the principal objection to their use? (*d*) Are there any books treating upon the subject? W. R., Sault Ste Marie, Mich.

ANS.—(*a*) The usual sand bricks are made of a composition of cleaning sand and some cementing material, such as Portland or Rosendale cement. These bricks are not burned, but depend for the stability of their structure upon the adhesive qualities of the cementing material. (*b*) Walls built of these bricks show good weathering qualities—that is, there is no serious deterioration evident. When built in the wall, these bricks will sustain the usual load that can be safely supported upon a good hard-burned clay brick. Bricks of this character laid in cement will safely carry from 150 to 200 pounds per square inch. (*c*) The principal objection to these bricks is due to their retention of water and the consequent liability to discoloration, this discoloration being especially marked in localities where salt air is prevalent. (*d*) The only work that we know of upon the subject is entitled, "Bricks, Tiles, and Terra Cotta," by Chas. T. Davis, the price of which is $5.00, and which may be obtained from the Technical Supply Co., Scranton, Pa.

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(258) (*a*) Please tell me what kind of paint to use on an air-cooling gasoline motor; something that will not be affected by the heat. (*b*) Please give me a method of case hardening that will produce colored effects. J. G. H., Green Bay, Wis.

ANS.—(*a*) Use asphaltum varnish. It will not give off any odor when dry. (*b*) If you wish to harden wrought or malleable iron, make an iron box and put the articles to be hardened in together with bone dust, fasten the cover on and fill the cracks with fireclay. Then submit the whole to a red heat for from 1 to 4 hours, according to the size of the articles and the depth you wish them to be hardened. Remove the box from the fire and turn the contents into clear cold water without exposing to the air. The color of the articles will be variegated. Instead of bone dust you can use saltpeter and leather scraps in the proportion of 8 parts of the latter to 1 of the former. Pack the articles to be hardened so that they will not come in contact with the sides of the box.

***

(259) Is the size of an air chamber on a pump made in accordance with the capacity of the pump, and how do you figure its size? I. E. D., Topton, Pa.

ANS.—For ordinary pressures and piston speeds it is the best modern practice to make the volume of the air chamber about 3 times the water-piston displacement per stroke for double-acting pumps, and to increase the volume for high pressures and speeds, making the volume about 6 times the piston displacement for fire pumps.

***

(260) Please inform me of the method of making wood alcohol. W. H. C., Portland, Me.

ANS.—Wood alcohol, or methyl, is a spirit obtained among other products, from the destructive distillation of wood. For the exact process of obtaining it, we should advise you to communicate with some manufacturing chemist.

***

(261) Which is the correct definition of an angle? An angle is the difference in direction of two lines that meet or tend to meet; or, an angle is the difference in direction of two lines that meet. H. J. W., Limwood, Pa.

ANS.—The second definition is to be preferred, though it can not be said that the first is wrong.

SCIENCE AND INDUSTRY

Vol. VII October, 1902 No. 10

FIRING A STEAM BOILER[1]

TO PERSONS unfamiliar with the requirements of modern boiler-room practice, and of the skill required to get the most heat out of a pound of coal, firing is merely shoveling coal into the furnace. When the boy from the farm begins the study of practical engineering he generally starts in the boiler room of some small mill or factory in a small town where the chief requirement of the fireman, or engineer, when the latter does his own firing, is to carry a steady steam pressure. The manner in which this is accomplished is usually of no particular importance, because the total weight of coal burned is small, and the value of the time spent in doing other work than keeping up the steam pressure and attending the engine more than offsets any small loss occasioned by unskilful firing. It is for this reason principally that those unfamiliar with the requirements of good boiler practice are led to believe that any one can fire a boiler who has sufficient muscle to shovel coal and who is not afraid of being blown to atoms at any moment.

A young man learning to fire a boiler in a large up-to-date plant generally learns but once, but the boy previously referred to generally learns two or three times, each time picking up certain kinks and methods, which gradually lead him to the position of skilful fireman. There are certain things connected with firing that cause loss or gain, and these should be thoroughly understood before attempting to fire a boiler in regular service. A few moments spent in considering those fundamental suggestions, which should be made to every fireman when starting out, will not only make the work easier, but will enable him to do better work and incidentally will render him more valuable to his employer. This means not only a steady job, but better pay, and the latter all wage earners are constantly seeking.

The fire under a boiler may be started in the same manner as in a cook stove or when building a bonfire, but the results are not satisfactory nor economical. This is because the conditions are not the same, and one of the chief requisites in a skilful fireman is the ability to study and to recognize a change of conditions.

In most boiler furnaces there is a strong draft, which is a most valuable thing to have, and it is important to know how to make the best use of this draft, for upon this depends to a great extent the success or failure of the fireman.

If we place a few shavings or a piece of oily waste upon the boiler grate, then light it and add a few fine kindlings, then coarse ones, and finally the coal, the fire will generally burn sluggishly and it requires considerable time to develop sufficient heat to

generate steam, and a long time to get a body of fire large enough to be spread over the entire surface. This is the experience of nearly all who employ this method. A better way is to cover the entire grate area with

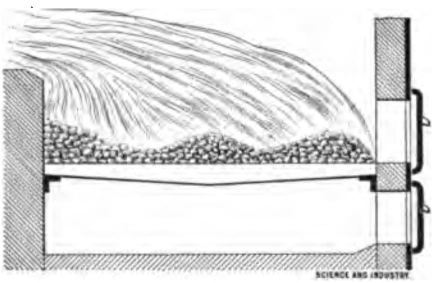


FIG. 1

coal, then with a hoe clear away a small space near the door and build the fire upon this area of bare grate. The waste or shavings will be found to burn up fiercely from the start and will require almost constant feeding in order to keep the fire at its height. This is due to the fact that practically all the air flowing from the ash-pit into the combustion chamber must pass through the small area cleared with the hoe. It has almost the same effect as a blast upon the fire, which enables an intense heat to be secured very quickly. The coal around the small initial fire soon ignites and in a very few minutes the whole grate is covered with a clean, bright fire. Where a boiler is shut off during the night, a few pounds pressure are frequently found in the morning, and it often happens that no coal need be put in after the fire is lighted, in order to raise the pressure to the desired point. This gives the fireman an opportunity to clean the pump, sweep up, or attend to other duties before beginning the day's work. Just before the engine is started fresh coal should be put in so that it will ignite and begin to burn briskly by the time the engine begins to draw steam from the boiler. By this means heavy firing when starting up is avoided, and it tends to keep the fires in good condition for a longer time.

No matter how much pains may be taken in endeavoring to spread the coal evenly over the grate surface, the fire will become uneven, the higher places becoming higher each time fresh fuel is added and the lower places relatively much lower. This condition is due to the fact that the air passes through the thinner layers of fuel much more readily than through the thicker ones, so that the coal is burned more rapidly, and consequently is more completely consumed, with the result that the thinner places do not increase in thickness as rapidly as the thicker ones. In a short time the surface of the fire will appear as shown in Fig. 1. This represents an uneconomical condition, because the larger part of the heat will be generated by the coal on the thinner places, while that on the thicker portions is baked and coked, and is consumed much more slowly. In order to have the fire burn uniformly over the grate, the bed of fuel should be leveled off, pushing the high places into the hollows and clearing the underside of the whole mass of ashes. A form of tool that has been found very efficient for both these operations

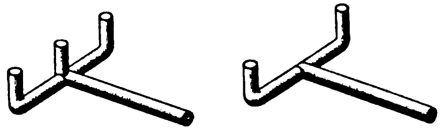


FIG. 2

is illustrated in Fig. 2. When leveling the fire and when raking out the ashes along the grate, the teeth or prongs should be turned upwards, as shown in Fig. 3, pushing the rake along on its back, and keeping it against the grate bars when raking out

ashes. Satisfactory results cannot be obtained by poking a boiler fire with one of the old-style pokers having the end bent at 90 degrees to the handle. All a boiler fire requires is leveling and having the thin layer of ashes under the burning fuel removed. Aside from this the less the fire is disturbed, the better, and it should be the aim of the fireman to introduce the coal, as far as it is practicable in such a manner as to keep the fire level so as to avoid leveling it oftener than necessary. With most coals, especially the bituminous varieties, the more the fire is disturbed, the greater is the tendency to clinker, and the formation of clinker results in a loss of fuel. When clinkers do form so as to cause the fire to burn sluggishly and with a yellowish flame, accompanied with more smoke than when the fire is clean, it is time to remove them.

Just before it is time to put in coal take the slice bar, the form of which is shown in Fig. 4, and beginning at the door slide it along the grate to the bridge wall. Then draw it back and run it under the bed of fire again and so on until the grates have been cleared. Do this through one of the fire-doors only. When the slice

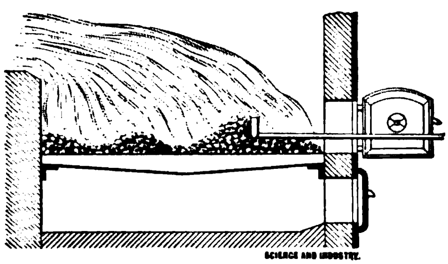


FIG. 3

bar gets under a clinker and has loosened it, bear down on the handle and raise the clinker to the surface, as shown in Fig. 5. The larger and more troublesome clinkers may then be removed by means of the rake, the prongs now coming into play in pulling the clinkers to the dead plate from which they may be pulled into a wheelbarrow or shoveled directly into the ash-pit. After clearing the grates with the slice bar and removing the

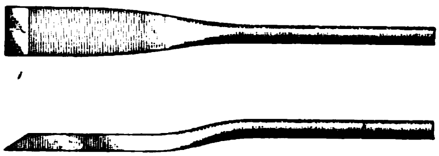


FIG. 4

clinkers thus brought to the surface, use the rake under the fire to clean out the fine ashes. Then cover this side with fresh fuel, and after it begins to burn briskly clean the opposite side in the same manner. These operations are usually completed in from one to three minutes, depending upon the size of the furnace, and unless the demand for steam is very great the steam pressure will not fall more than a pound or two. With ordinary good coal the rake will have to be used once during each hour and a half or two hours, and the slice bar, probably twice during a half day's run. This is assuming that a coal which clinkers somewhat is employed, but there are a number of coals which seldom if ever require the use of the slice bar.

At noon the fire will need a thorough cleaning, which cannot readily be accomplished without the hoe. There are various methods of cleaning fires used by different firemen, many of which are very good; in fact, it is frequently six of one and half a dozen of the other as to which one is employed. A very satisfactory method consists in waiting until the fire has burned low, when all the dead coals will be plainly visible. With the hoe push back the upper layer of coal to the bridge wall, as shown in Fig. 6, then hoe out the dead coals through the fire-door.

After cleaning the grates thoroughly pull down the pile of live coals, spread them evenly over the clean grate and cover with a thin, even layer of fresh coal. When this coal becomes thoroughly ignited open the opposite furnace door

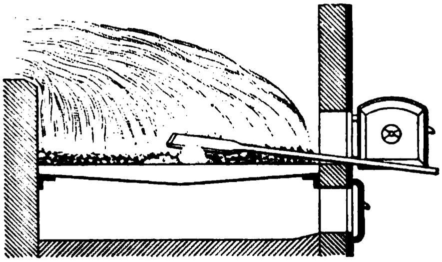


FIG. 5

and clean the remainder of the grate. This is one of the quickest methods of cleaning fires and one that permits very little drop in pressure; in fact, grates are successfully cleaned in this manner when the boiler is worked to its capacity. Some dead coals and ashes are, of course, left next to the bridge wall, but as many of these can be removed the first time the rake is used, they do not cause a waste of fuel nor render a considerable part of the grate surface inefficient. It is well to keep the damper partly closed when cleaning the fires.

In many places it is desirable to bank the fires at night, especially in winter. There are a number of methods of banking, some good and some bad, some requiring 200 pounds of coal and others 500 pounds in order to secure the same results. The actual weight of coal required to bank a fire successfully depends upon several things, such as the size of the furnace, the size and quality of the coal, the efficiency of the damper and means for regulating the inflow of air above and below the fire, and whether the steam pressure is to be partly maintained or merely a bed of live coals retained until time to start in the morning. The quantity of coal required also depends upon the length of time it is desired to have the bank last. Where a night watchman is employed considerable coal may be saved during the winter by instructing the watchman how to bank the fire so that the hot fire when shutting down may be allowed to burn down and the furnace to cool somewhat before the bank is put in. In this way it is possible to save from 100 to 200 pounds of coal per night, depending upon the size of the furnace and upon the method of banking employed, and still secure the same results next morning.

A simple method of banking a fire, and as good a way as any, consists in pushing the upper layer of coals back against the bridge wall in the same manner as when about to clean the fire. Then cover the live coals with fresh coal, which has been previously wet. The damper is to be nearly closed and the drafts in the fire-doors and ash-pit doors tightly closed. Some air will always leak in and this is generally more than sufficient to keep the fire alive. The coal for the bank should preferably be wet some time before banking so that the surplus

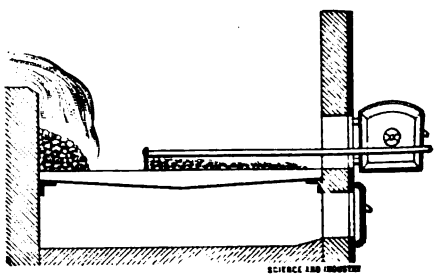


FIG. 6

water may drain off. Fine coal is preferable to coarse coal for this purpose, as it usually forms a crust about the live coals and retains the heat a much longer time. The depth of fresh coal should seldom be less than

six or eight inches and from this to twelve inches, depending upon the inclination of the bank. The flatter the bank, the deeper the coal should be and vice versa.

When preparing to start in the morning, the dead coals and ash on the grate are hoed out of the fire-door and the grates thoroughly cleaned back to the bank. By running the rake under the bank much of the ash can readily be worked through into the ash-pit, leaving a good body of clean, live coal. Now pull down the bank and spread it evenly over the grates and cover evenly with fresh coal. The damper and drafts should then be opened until the fresh coal has been thoroughly ignited and most of the smoke has passed off. The time between raising steam and starting the engine can generally be put to no better use than cleaning the tubes. Boiler scale is a poor conductor of heat, but soot is still poorer, and the fireman who aims to make a good showing in the use of fuel cannot afford to neglect this important duty. Firemen when asked how often the tubes of a boiler should be cleaned, generally reply, "at least once a week." It is certain that this is absolutely the least often, especially with bituminous coals. When using soft coal, once in twenty-four hours is none too often for a boiler that is in service ten hours during this time, and for boilers in operation twenty or twenty-two hours out of the twenty-four, the tubes should be thoroughly cleaned during both the day and night shifts.

There are various devices in use for cleaning tubes. These comprise scrapers, brushes, and steam blowers. When dry steam can be had the blower, illustrated in Fig. 7, furnishes a very effective and convenient method. With boilers of 16 feet in length and over the blower does not always remove all the soot from the rear ends, with the result that a crust forms on the tube surfaces and prevents, not only the passage of heat into the water, but the thorough blowing of the tubes. For this reason it is a good plan to use a tube brush or scraper at least once a week, say, Sunday morning, to loosen these deposits, using the blower during the week.

The steam pressure should be raised to at least 60 pounds before using the blower. Observing this will tend to lessen the formation of crust at the rear of the boiler, which can only be removed by a scraper, although sometimes tube brushes are efficient.

Tube-cleaning tools when of good

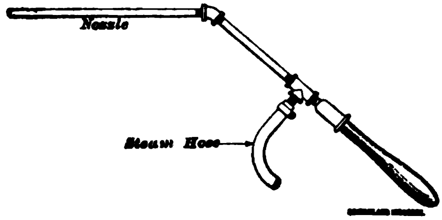


FIG. 7

quality seldom fail to prove a paying investment, especially when smoky fuels are employed. The steam blower is probably the cheapest tube-cleaning appliance for daily use owing to the greater saving in time, but the scrapers and brushes are equally important, although not used so often. The latter tools should by all means form a part of the boiler-room equipment. A straight-shot blower will be found as effective as any other form of nozzle and is easily made of pipe and ordinary fittings. The length of the nozzle entering the tube should be as near one-fourth of the length of the tube as it is practicable to use it, and the pipe conducting steam to it should be thoroughly blown out and warmed before introducing the nozzle into the

tubes. Always use steam of full pressure.

The foregoing directions, as will be noticed, apply particularly to hand-fired furnaces with stationary grates. It requires considerable skill to fire a boiler with stationary grates, and not the best quality of coal, and be able to make a good showing in dollars and cents. With a good shaking or dumping grate it is much easier, especially with good coal, but even then there are firemen who make bad work of keeping a clean, bright fire. One difficulty noticeable with a good many firemen is, that they do not use the shaking grate often enough. When the fire is permitted to fill up with ashes and clinker, and then five minutes or more is spent in shaking the grate, the object of the shaking grate is defeated and the results far from what might readily be obtained. The object of the shaking grate is as much to keep the fire clear of ashes, as to remove them after they have accumulated to such an extent as to seriously affect the fire, and much better economy can be secured by keeping the fires well freed of such accumulations. A good plan is to keep the shaker lever in place all the time when burning slack or other coal yielding immense quantities of ash, then before putting in the fresh coal move the lever back and forth once or twice, as may be necessary. In this way the ashes are removed as fast as formed and accumulations are impossible while the fire is kept clear and bright, which condition is most favorable to getting the greatest amount of heat from a pound of coal. The ash-pit should never be allowed to fill up with ashes. These should be removed often enough to keep the level in the pit at least a foot from the bottom of the grates. When the pit fills up farther than this the fire will be found to burn briskly at the front of the grate and sluggishly at the rear, which causes a partial waste of the fuel placed at the back of the furnace.

There are probably as many ways of firing boilers and of keeping the fire as there are kinds of coal. Nearly every fireman has some little difference to offer, which, to him is essential to good results. This is not at all surprising when we stop to consider the almost endless variety of conditions possible in the operation of steam boilers, and that the requirements of each variety must be successfully met in order to obtain the best possible results. It is for this reason that the same method and the same coal and the same man will not always give the same results in different plants. Some firemen carry thick fires and others, very thin fires. Some firemen fire heavily while others employ the "little-and-often" plan. Some fire one boiler at a time, or one side of the furnace at a time, if a single boiler, while others fire the whole at once. It is evident that the successful fireman must study closely the conditions found in the plant in which he is employed, because it requires no lengthy argument to show that a single method does not and cannot be expected to give good results in all plants, that is to say, under all conditions. The intensity of the draft and the size of the coal have, perhaps, the most important influence upon the methods employed. For instance, when a coarse coal is employed, and the draft is strong, the depth of the fire may be ten or twelve inches, and even deeper, but should the draft be weak, the depth must be less in order to get sufficient air through the bed of coal to consume the required amount in a given time. With fine coal and a strong draft the depth may be from

four to eight inches with good results, but with a weak draft the depth should be decreased to from three to five inches. With shaking grates, which are adapted to burning fine coal of a low grade, a thin fire may be carried while firing moderately heavy. When this can be done it is preferable to the "little-and-often" plan, because it avoids the frequent opening and closing of the furnace doors. By working the shaker lever each time fresh coal is thrown in, the depth of the fire in many cases can be kept not only of uniform thickness but free of ashes, and it also serves to break the crust forming over the surface of the bed of fuel, thus permitting a freer passage of air through it. The formation of the crust over the surface of fine coal, bituminous coal particularly, is one of the greatest drawbacks to firing slack coal by hand with good results. Any method that will permit the breaking of this crust without having to stir the whole bed of coal, and without opening the fire-doors at frequent intervals, will greatly aid in securing economy.

The ideal outfit for a plant in which the boilers are hand fired with poor coal of small size is a good draft, shaking grates, and plenty of grate surface so that the fire can be kept thin and clean, and as rapid combustion as possible secured. When coarse coal of good quality is employed the conditions are reversed and another method may give better results. In this case the grate area may be less, the quantity of coal introduced at a time increased, and the coal put in less often. The fire may be carried deeper and still obtain the same rate of combustion. Where the boilers are connected together and the load is light the alternate plan of firing may be used to good advantage, that is, one boiler may be fired at a time and when the coal is thoroughly ignited and most of the smoke has disappeared, the other boiler is fired. This tends to keep about the same temperature in the furnace, considering the two boilers as a unit, and the evaporation is more uniform. If two boilers were to be fired simultaneously the steam pressure will be found to fluctuate owing to the two fires reaching their height at the same time and dying down at the same time. The tendency to fluctuations may be checked by closing the damper, but unless the pressure and the fires are watched very closely, the draft will not be regulated at just the right time and a waste of fuel will follow. The alternate method with light loads gives

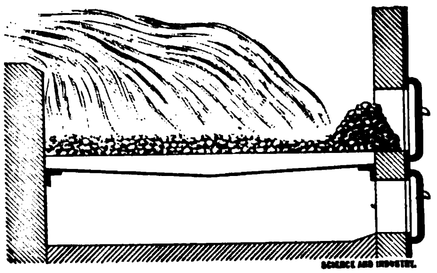


FIG. 8

better combustion, and on the whole is more economical.

In cities, where the production of smoke is offensive and is prohibited much can be done to avoid the nuisance by providing plenty of boiler capacity, and by adopting the coking plan of firing. This consists in piling the coal just inside the fire-door, as shown in Fig. 8, and permitting the volatile matter to bake out of it. Then take the rake and push it back over the bed of incandescent coals and replace by another pile of fresh coal. By this means coke is burned instead of green coal, and the volume of smoke incident to the use of the latter, almost wholly avoided.

When a light, flashy coal is employed which burns too quickly for good results, it will behave better if wet. This does not imply trying to burn coal dripping wet, however, but rather damp coal. The coal may be thoroughly wet and then permitted to drain before it is used. Wetting a flashy coal has about the same effect as wetting gunpowder, viz., it causes it to burn more slowly, which is oftentimes of great advantage. It is obvious that a slow-burning coal should be used dry, the dryer the better. Keeping water in the ash-pit does not add anything to the air nor does it aid combustion to any appreciable extent, if at all, but it does tend to keep the grates cool and prevents warping. Where water is not needed for this purpose it is better not to use it. There is no good reason for doing useless things around a boiler room, because there are so many things requiring a great deal of hard work which are absolutely necessary for the best results.

When a fireman makes a change of positions he must become an experimenter on a small scale. This requires good judgment, the price of which is experience.

USEFUL FORMULAS—IX

JOSEPH E. LEWIS, S. B.

Composition and Resolution of Forces

IN Article VIII of this series, we had something to say about force and its action upon matter, as illustrated in the motion of bodies through space, with special reference to falling bodies; but we did not say very much about force itself, and in fact, there is not very much that we can say to really explain what force is. We are so used to seeing the operation of the force of gravity, for instance, that we cease to notice or reason about it. It is so common a thing to see a body fall to the ground that few of us ever ask ourselves, as did Sir Isaac Newton, why it falls downward and not upward. And yet, there is nothing that we can see to cause one motion any more than the other. That the force of gravity is one of attraction and not of repulsion is merely a matter of fact, for which it would be pretty hard to find a very satisfactory explanation. It will not, therefore, be worth our while to spend too much time in trying to understand what force is, but we can profitably spend a great deal of time in learning about the different kinds or manifestations of force, and in studying the ways in which forces are employed. It is our purpose in this article to discuss the individual and the combined effect of several forces all acting upon a single body at one time.

In our discussion of falling bodies we made reference to the First Law of Motion; namely, that a body continues in its state of rest or of uniform motion in a straight line unless compelled to change that state by an external force. In the present article we shall have to do with the Second Law of Motion, which is sometimes stated as follows: "A given force will produce the same effect whether the body on which it acts is in motion or at rest; whether it is acted on by that force alone or by others at the same time." Now when several forces of varying intensity act upon a body in different directions at

the same time, the body does not move in the direction of any one of the forces, but instead moves in a direction and at a velocity determined by the combined action of all the forces together. This is called its resultant motion, and may be a straight line or a curve according to the forces acting. When the forces acting do not vary in their relative magnitudes, the resultant motion is in a straight line. When they do vary, or when one force acts only for an instant and the other acts continuously, the resultant motion is a curve. A curve results, for example, when a projectile is fired in a horizontal line. The force of the exploding powder gives it a uniform motion at a constant or nearly constant velocity. We say nearly constant because the resistance of the atmosphere acts to retard it. The force of gravity, on the other hand imparts to it a variable motion, so that while its tendency to move horizontally is at a uniform speed, its tendency to move downward is at a uniformly increasing speed. The resultant is, therefore, a curve which starts horizontally and curves downward. This curve is technically called the parabola.

Let us return now to a consideration of forces which act simultaneously, which do not vary in their relative intensity, and which, therefore, have a relatively uniform effect upon the body,

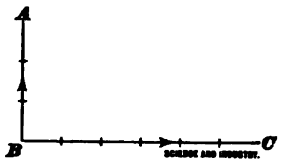


FIG. 1

so that it moves in a straight line. In this case, if we know the point of application, direction, and magnitude of each of the component forces, we may find the magnitude and direction of the resultant force. This process is known as the Composition of Forces.

Three cases may arise:

(1) When the given forces all act in one and the same direction. The resultant is then the sum of the given forces. The motion produced is in the

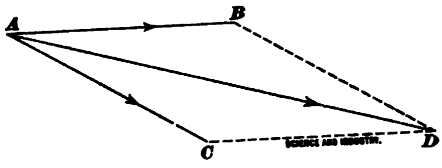


FIG. 2

line of their mutual action, and is the direct sum of the motions which would be produced by each force acting alone. Take, for example, a steamship moving down stream under the combined influence of the current and her engines. Say the current is 3 miles an hour, and the engines alone are capable of driving her at the rate of 8 miles an hour. The resultant speed would be the sum of the two, or 11 miles per hour. It is quite easy to see the truth of the Second Law of Motion in this case. It is easy to see that the current and the engines each produce practically the same effect whether acting alone or in conjunction with the other.

(2) When the given forces act in directly opposite directions, the resultant is then the difference between the given forces and the motion is in the direction of the greater force. For example, suppose the steamship to move up stream propelled by her engines. Her speed will now be 5 miles per hour, or the difference between the two speeds.

(3) When the given forces are at an angle, the resultant force is then obtained by the triangle or by the parallelogram of forces. Suppose the ship moves across the stream. The current takes her down stream at the rate of 3 miles an hour, and she travels across at the rate of 8 miles per hour. Her actual

motion will be diagonally across instead of straight across.

We have used the very simple illustration of the ship in order to make the elementary principles of the subject perfectly clear, but the principles them-

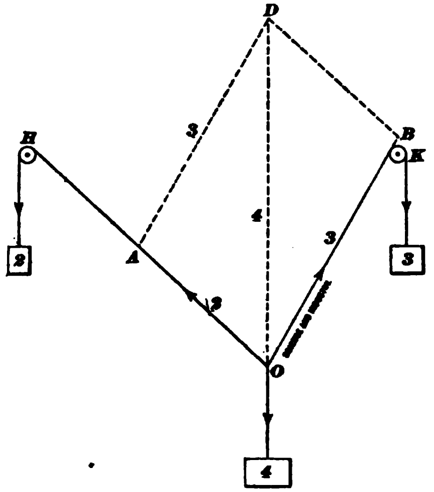


FIG. 3

selves have a very wide application in mechanics and engineering, in the designing of machinery and in the building of bridges, structural steel work, and masonry. In working out problems involving the composition and resolution of forces we may represent the forces by lines, the point of application fixing one end of the line, the direction of the force determining the direction of the line, and the magnitude of the force determing the length of the line. By drawing lines in this way to scale, the units of force being equal to the units of length, we have a complete graphic representation of the forces under consideration.

The unit of length may be determined by convenience, but having once determined upon the scale it must be adhered to throughout the problem. Thus Fig. 1 represents two forces applied at the point B and acting at right angles to each other. The arrowheads indicate that the forces represented act from B towards A and C, respectively. The force $B\ A$ equals 3 pounds and the force $B\ C$ equals 6 pounds. Therefore, the line $B\ A$ is 3 units long, and the line $B\ C$ is 6 units long.

Of course when the forces act in the same line as in cases (1) and (2), there is no need of a graphic representation, since the resultant is determed by simple addition or subtraction, but in case (3) a graphical representation becomes necessary. Fig. 2 represents what is known as the *parallelogram of forces*.

Let $A\ B$ and $A\ C$ represent in direction and magnitude two forces acting at the point A. The resultant force is $A\ D$, found by completing the parallelogram. This diagonal line $A\ D$, is a complete graphical representation of the resultant force, since it shows its exact direction and magnitude. The two forces $A\ B$ and $A\ C$ are called components. In this same way we may determine the resultant of any two components.

If two forces such as those represented in Fig. 2, act simultaneously upon a body at A, that body will move in the direction $A\ D$ and come to rest at D. Suppose that instead of acting together these forces act successively, $A\ B$ acting first, and then $A\ C$. The body will move from A to B, and then from B to D, coming to rest at D. Thus we see that these two forces produce

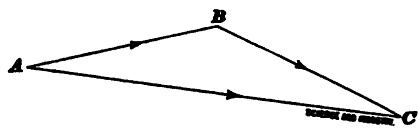


FIG. 4

the same effect whether they act simultaneously or successively, which is precisely what is stated by the Second Law of Motion.

A very satisfactory demonstration of the truth of this principle of the paral-

lelogram of forces may be had by using a simple apparatus illustrated in Fig. 3.

Upon a vertical board or wall fasten two freely moving pulleys *H* and *K*. Knot three pieces of string at *O*, and having fastened to them three weights weighing, respectively, 2, 3, and 4 pounds, throw the 2- and 3-pound weights over the pulleys, as shown. When the apparatus has ceased to vibrate the parallelogram *A O B D* may be completed, making *O A* equal 2 units of length, and *O B* equal 3 units of length. It will be found that *O D* will be in the direct line of the 4 pound weight, and will equal 4 units of length.

The triangle of forces is a simpler solution of the problem than the parallelogram. See Fig. 4.

We have two forces whose direction and magnitude are represented respectively by the lines *A B* and *B C*. The line completing the triangle is the resultant.

We will now take a case where it is required to find the resultant of more than two forces. See Fig. 5.

Let *A B*, *A C*, *A D*, and *A E* represent in magnitude and direction four forces acting at the point *A*. Now we may combine any two by the parallelo-

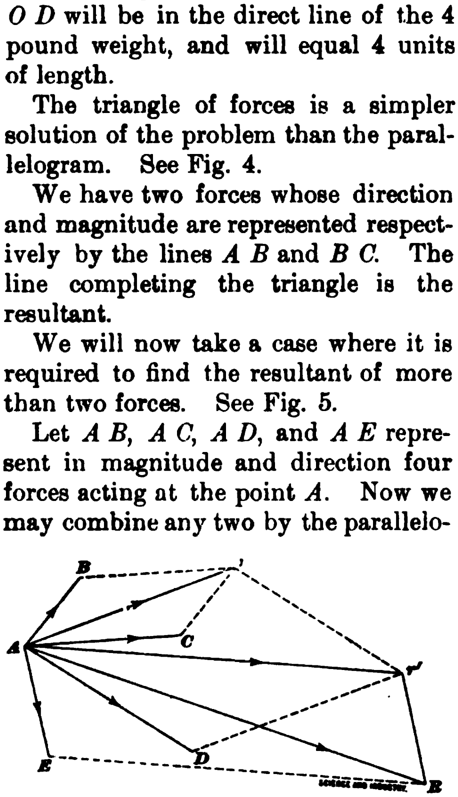


FIG. 5

gram of forces as already explained. We may then combine the resultant with one of the other forces to give a new resultant, and so on until every force has been taken account of. The last resultant will be the resultant of all the forces. Thus in Fig. 5 we combine *A B* and *A C* to give the resultant *A r*. We now combine *A D* with *A r* giving a new resultant *A r′*, which in turn is combined with *A E*, giving the final resultant *A R*.

This makes a somewhat complicated

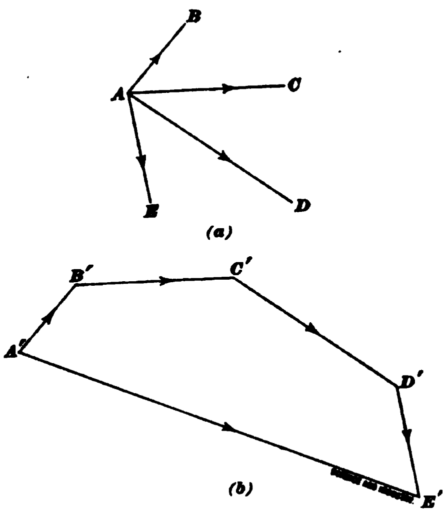


FIG. 6

diagram, especially if there is a large number of forces. A simpler diagram is that known as the polygon of forces which bears about the same relation to the solution given in Fig. 5 as the triangle of forces does to the parallelogram of forces.

In Fig. 6 (*a*) we have the problem, four forces acting at the point *A*, as in Fig. 5. Fig. 6 (*b*) gives the solution by the polygon of forces. It consists in laying off the line *A′ B′* in the same direction and of the same length as *A B*, *B′ C′* in the same direction and of the same length as *A C*, *C′ D′* in the same direction and of the same length as *A D*, and *D′ E′* in the same direction and of the same length as *A E*. Then draw the line *A′ E′* which represents the resultant.

Perhaps it will make the polygon of forces clearer to imagine a body at *A′* acted upon by the four given forces in

succession. It will first move to B' over the path $A' B'$, then to C', then to D', and then to E', where it will come to rest. If all of the forces act simultaneously, the body will move to E' over the path of the resultant $A' E'$.

The principle of the polygon of forces

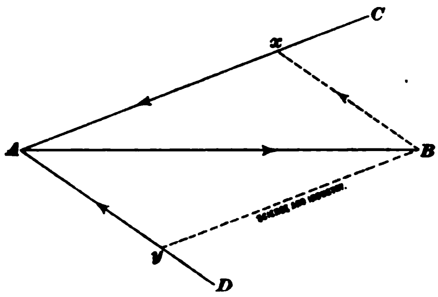


FIG. 7

may be stated as follows: If a number of forces be in equilibrium, they may be graphically represented by the sides of a closed polygon taken in order. If the forces are not in equilibrium, the lines representing them in magnitude and direction will form a figure which does not close.

So far we have considered forces acting in the same plane. If we have forces given acting in two planes we may find the resultant of those in each plane separately. The two resultants may then be combined in a plane common to them both.

In designing machinery, it is frequently of the utmost importance to be able to determine the resultant of several forces acting on a given part in order to properly determine its size, shape, and position. This is a factor of even greater importance in designing trusses and bridges.

In both cases it is frequently just as important to find the components of a given force. That is to say we have a force of known magnitude acting in a given direction, and it is required to find two or more forces acting at different angles, which will just balance the given force. This is known as the resolution of forces and is just the reverse of the composition of forces.

In Fig. 7 we have a force $A B$, and it is required to find two forces acting in the directions $C A$ and $D A$, which will just balance it.

Draw $B x$ parallel to $A D$ and $B y$ parallel to $A C$, then $B x$ and $x A$ are the two forces just balancing $A B$ and $A x$ and $A y$ are the two forces whose resultant is $A B$.

We will close with a simple practical example of the resolution of forces. In Fig. 8, we have a load carried by the truss $A B C$ at B. The timbers $A B$ and $B C$ are framed together at B and are supported at A and C, respectively. It is required to find the compressive stress in these two timbers in order to properly determine their size.

Draw $x y$ parallel to $B A$ and $x z$ parallel to $B C$. Then if $B x$ represents the magnitude of the weight, $x y$ will represent the stress carried by $A B$ and $x z$ that carried by $B C$. Knowing the weight in pounds, we can readily scale off from the diagram the magnitude of these stresses, which will give us the

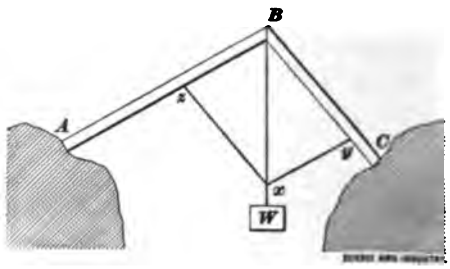


FIG. 8

necessary data from which to proportion the sizes of each of the timbers. This is of course a simple case, but every problem in design where we have to deal with forces, resolves itself into a series of cases of a very similar nature.

Problems of this kind, or involving

this principle, are encountered almost every day by designing engineers, and it is of vital importance that the principle be thoroughly understood. Its discussion comes properly under the head of mechanics, and any one desiring to do so can make a more thorough study of the subject by consulting any of the numerous books on applied mechanics.

THE AMATEUR'S LABORATORY—I

R. G. GRISWOLD

EVERY youth interested in scientific studies has undoubtedly longed to possess a laboratory in which he could carry out experiments in the various subjects that engrossed his mind. Many have been deterred from establishing such by the apparent difficulties to be overcome in constructing the apparatus, for lack of tools or skill in mechanical handiwork, or the great cost of the apparatus if purchased. These difficulties have little foundation, however, and often eclipse the great benefit and pleasure to be derived from one's own laboratory, the insatiable desire for knowledge that it induces, and the great simplicity of much of the apparatus or the ease with which it lends itself to simple construction.

This series of articles contemplates the description of accurate though simple apparatus, as constructed by an amateur for his laboratory and tests that can be made therewith. The greatest requisites in such constructions as will be described are close attention to detail, and patience. The sensitiveness of a piece of apparatus may be greatly impaired by haste or impatience in adding the finishing touches. The tools required are few, the materials usually cheap and easily obtained, and it may be safely conceded that students in the electrical and mechanical lines possess some knowledge of tools and their uses.

In making a piece of apparatus for laboratory use, some specific object is to be attained, generally measurement. The accuracy of any measurement depends greatly upon the sensitiveness of the instrument with which it is made, and for this reason care should be exercised to have the instrument as perfect and substantial as possible. All apparatus should be neatly finished, as it adds greatly to its appearance and durability.

The room selected for one's laboratory should be on the top floor of the house, where it will be dry and well lighted, and not likely to be disturbed. As a last resort, but only as such, a portion of a very dry cellar may be used, but cellars are generally damp, poorly lighted, and very apt to be dusty, especially if they contain a heater and coal bin. The room should be provided with at least two benches or tables, one for experiments and the other, a work bench for the construction of apparatus. If the room contains two windows, a bench may be placed before each so as to derive as much benefit from the light as possible. If the room is not finished in a light paper or plaster, it should be given a coat of whitewash, which will reflect the light to the darker portions not directly illuminated by the windows.

The work bench should be very rigid, and the one shown in Fig. 1 will be found convenient, easily constructed and moderate in cost. It is 2 feet wide by 4 feet long, which length may be

increased if desired. A portion of the back is cut away at *a* to allow plenty of light to fall upon the vice, which is fastened on at *b*, the square opening giving access to the clamping screw. The backboard should be provided with racks for the tools, made by boring holes in strips of wood for them to slip into. Larger tools, such as the brace, saws, clamps, glue pot, etc., may be hung on nails driven into the rail *c* underneath. The drawer at the right may be divided into compartments for small tools, nails, screws, etc. The drawer pulls may be made either of wood, as shown as *d*, or two porcelain knobs may be purchased and screwed on. The left-hand drawer slide is supported at the rear end by the piece *e*. The front top board is slightly raised above the one behind and its edge beveled off, which allows the tools to be pushed back out of the way and prevents them from rolling off or getting under the work in front. The lumber should be planed and all the joints made with glue before putting in the nails or screws, which, when thoroughly dry, will make a very stiff bench. The method of joining the front legs and the top pieces is shown at *f*. The back legs are simply pieces cut from 1-inch lumber. The shelf underneath is for boxes, paint cans, etc.

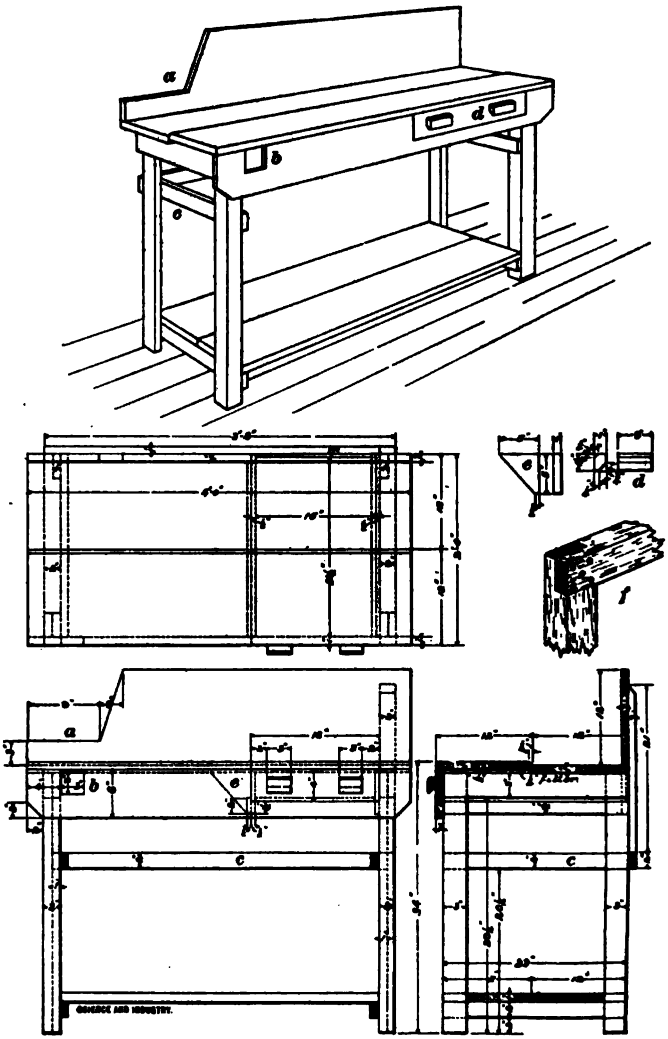


FIG. 1

After the bench is finished, it should be well sandpapered until smooth, and then given two or three coats of orange shellac, which will make a fine finish.

Allow each coat to dry before applying another.

While there are only a few tools absolutely necessary, it will pay to have these of a very good quality. Many tools can readily be made, such as small screw drivers, center punches, cold chisels, etc. The amateur should provide himself with the following tools: An 18-inch hand saw with 14 to 16 teeth to the inch; a compass saw with teeth as fine as can be had; a small iron block plane with a bit $1\frac{1}{2}$ inches wide; one $\frac{1}{2}$-inch and one $\frac{1}{4}$-inch chisel; one brace; one expansion bit ranging from $\frac{3}{8}$ inch to $1\frac{1}{4}$ inches; one $\frac{1}{4}$-inch and one $\frac{1}{8}$-inch auger bits, and one $\frac{3}{32}$-inch gimlet bit; one $\frac{1}{16}$-inch and one $\frac{3}{32}$-inch brad awl; one medium weight claw hammer and one very

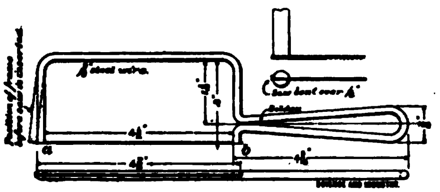


FIG. 2

light ball-peen hammer; one pair small pliers; one pair pincers; two small three-cornered files, 4-inch and 7-inch; one round file, not over $\frac{1}{4}$ inch diameter; one 4-inch flat file, smooth cut with one safe edge; one 8-inch second cut flat file with one safe edge; one small hand drill with set of twist drills ranging from $\frac{3}{64}$ inch to $\frac{3}{16}$ or $\frac{1}{4}$ inch; one $\frac{1}{2}$-inch cold chisel; one bench vise with 2-inch jaws; one 2-foot rule; one 3-inch scale with 8ths, 16ths, 32nds, and 64ths on one side and 10ths and 100ths on the other; one pair of dividers; one 2-pound soldering iron; solder and rosin; one 6-inch try square; sandpaper and emery cloth of several grades, including the finest; one 1-pint can of LePage's glue; a small quantity of orange shellac; one pound of paraffin wax and wire nails and brads of assorted sizes. Brass screws and copper wire can be secured as needed. Other material will be described as the apparatus requires it.

A very convenient hack saw, which can be used for all small work, is shown in Fig. 2. The frame is bent to the size indicated from $\frac{3}{16}$-inch steel wire. The saws are those used for scroll sawing, and may be secured at any hardware store. When the frame is bent to shape, fasten one end of a saw in the vise, teeth upwards, holding the other end with the pliers, and move the ends of the frame to and fro on the blade until slots are cut deep enough to hold the saw as at *a*, *b*. Now heat the ends of the saw until red and bend about $\frac{1}{16}$ inch over at right angles, which, when cold, will serve to hold the blade in the frame. By springing the ends of the frame towards each other the saw may be inserted, the tension holding it firmly in place.

The first essential in electrical experiments is a source of electricity, either a battery or dynamo. Since the latter is rather expensive to build and operate, a very efficient form of plunge battery will be described, which, for small laboratory experiments, is all that can be desired. The battery is shown in Fig. 3. The glass jars are made from the quart size Mason's fruit jar. Secure four and cut off the small neck so that the resulting jar will be about $5\frac{1}{2}$ inches high. This is accomplished by drawing a red-hot poker slowly around the jar on the line of cutting when a crack will be seen to follow the iron and a slight tap will sever the top with a clean edge. Should the crack fail to start, touch the heated spot with a small drop of water. Smooth off the sharp edges with a file wet in turpentine. Now get from some electric light or supply company 40 pieces of arc-light carbon

about $6\frac{1}{2}$ inches long. The pieces discarded by the trimmers will serve the purpose well. As these carbons are generally copper plated, it will be necessary to remove this coating for about 5 inches by washing it with nitric acid, applied with a tuft of cotton on a stick. As soon as this coating is dissolved, wash the carbons thoroughly in water and place in an oven to dry. Do not allow the acid to come in contact with the skin or clothing, and avoid breathing the brownish-red fumes that are given off.

The supporting board for the carbons *a* should now be cut out of some hard wood, well seasoned. Bore the holes for the carbons and zinc as indicated at *b* for each cell. As these carbons vary slightly in size from the standard $\frac{7}{16}$ inch or $\frac{1}{2}$ inch, the expansion bit will enable a good fit to be made. After boring the holes, sandpaper the wood well and finish as described below, either in a natural or stained color.

Place the copper-plated ends of the carbons in the holes so that they will protrude on the upper side about $\frac{3}{16}$ inch, fastening them in place with small wooden wedges. By placing the board top side down on two $\frac{3}{16}$-inch pieces and letting the ends of the carbons rest on the bench, they may all be put in so that their tops are perfectly even. Clean the protruding copper-plated ends with very fine emery cloth, and starting from the position shown in the plan, wrap a well-cleaned bare No. 16 or 18 copper wire around them, as at *c*, twisting the free ends together so as to leave about 5 inches to attach to the bonding posts *g*, *g*, *g*. When all

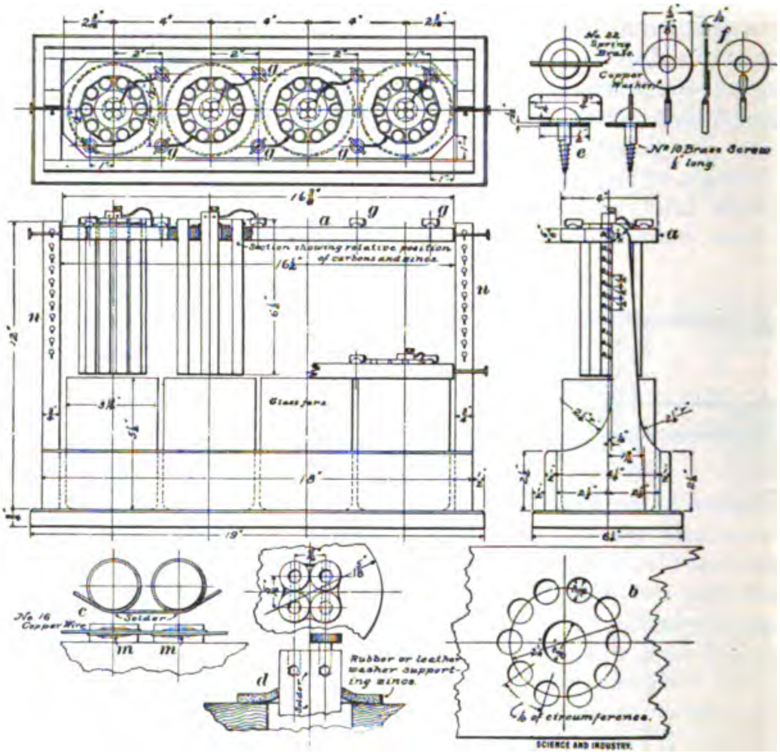


FIG 3

the carbons have been wrapped, solder the wires to the carbons at *m* which the copper plating will render possible. As the carbons are apt to carry the heat from the soldering bit very rapidly, they should be warmed in an oven first. When the soldering is completed, give all the exposed work on top of the board three good coats of shellac, allowing one to dry thoroughly before applying another. On the under side, work the shellac in well between the carbons and the board. At the ends of the board are driven two "ten-penny"

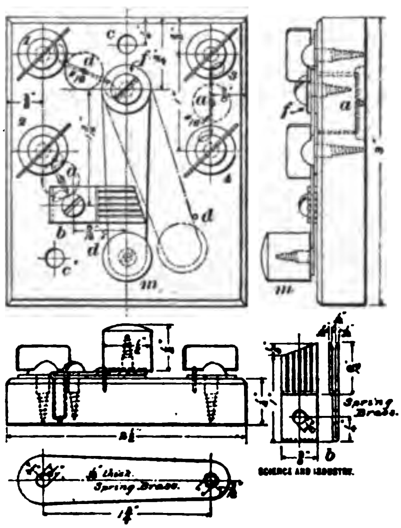


FIG. 4

wire nails, for raising and lowering the system into the electrolyte and supporting it at any desired point.

The zincs are made by soldering together four ordinary battery zincs as at *d*. Join two together by soldering them for 1 inch at the top, and then the other two in a similar manner. Then put the two pairs together and treat them likewise. The lower 5 inches should be thoroughly amalgamated before soldering by dipping them into dilute sulphuric acid until bright and clean and then rubbing them with mercury until a good coat adheres. If this is not done first, difficulty may be experienced in getting the mercury to flow between them. As only one binding screw is now necessary for the zincs, the other three may be taken out. The supporting washer, which is made of $\frac{1}{8}$-inch leather or rubber $1\frac{5}{8}$ inches in diameter, should have the hole small enough to bind tightly on the zinc to prevent its slipping through.

The battery box should now be completed and the small brads at *n* driven in at half-inch intervals. Make the box of the same wood as the supporting board, well seasoned, and put together with glue, using only enough thin wire brads to hold it together while drying. Finish in the same manner as the supporting board.

When wood is used in the construction of apparatus, it should be hard and well seasoned. Mahogany, cherry, and walnut are without doubt the most satisfactory, but more expensive than white pine, poplar, chestnut, oak, or ash. So much dependence must be placed upon the wood with regard to warping, however, that it proves economical to purchase the better varieties. For cases, boxes, etc., the cheaper woods will do, but for the bases of instruments where any change of form would destroy the accuracy of the readings, only well-seasoned hard wood should be used.

After the piece is cut to size and all holes bored, it should be finished as follows, using for an example, a piece of mahogany. Sandpaper the entire surface to be finished with very fine paper, rubbing only in the direction of the grain and not across it; then rub well into the pores of the wood a dark mahogany filler, wiping off the excess just before it dries. When dry, stain the wood with a mahogany stain and allow it to dry, afterwards wiping the

surface with a cloth moistened in turpentine to remove any stain on the surface that has not gone into the wood. Now apply a thin coat of varnish, rubbing it down smooth with fine sandpaper when perfectly dry. Apply two more coats, when the wood will have a rich, red color and a high gloss. Give the under side one coat of varnish to prevent the absorption of moisture. Cherry, oak, and walnut, may be treated in a similar manner.

The binding posts are simple, inexpensive, and efficient. They are made by soldering a piece of No. 22 spring brass into the slot of a No. 9 or 10 round-head wood screw, ½ inch long, as shown in detail at *e* and *f*, Fig. 3. The copper washer, which is ½ inch in diameter with a hole just large enough to admit the body of the screw, has the flattened end of the wire from the carbons or zincs soldered to it on the under side. A couple of small copper or galvanized tacks may be soldered to the back at the same time as the wire, to be forced into the wood, securing the washer in place. After the screw has been run in for its full length it should be withdrawn and the thread end only dipped in a little melted paraffin and then replaced. This will cause it to work smoothly. The batteries may be connected in series by connecting the zinc of one cell to the carbon of the next, or in multiple by connecting all the zincs together, and all the carbons together.

The battery is now ready for charging. The electrolyte or exciting solution is made up as follows: three parts of potassium bichromate are dissolved in eighteen parts of water, and then four parts of sulphuric acid are added while the solution is stirred vigorously. About six pints of this solution will be necessary to fill the four cells and the solution should come about ½ inch from the top of the jar when the carbons and zincs are lowered into place. The E. M. F. (electromotive force) of each cell will be about 1.9 to 2 volts, and when all four are connected in series the battery will give from 7.6 to 8 volts. The output can be varied by raising or lowering the elements by means of the small brads at the sides.

To control the current, switches are necessary, and the following will be found serviceable. Fig. 4 shows a switch for opening or closing a circuit and its construction should be easily understood from the sketch.

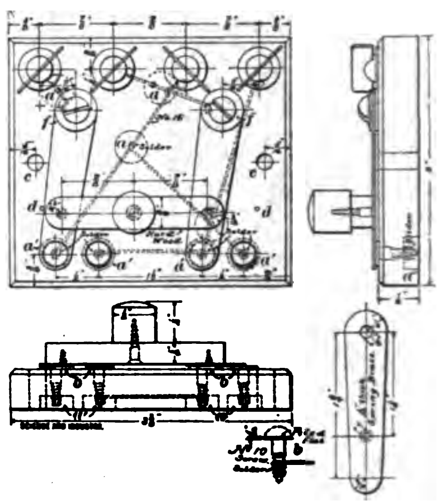


FIG. 5

The jaw *b* has saw slits made in it with the hack saw already described, so as to give twelve points of contact instead of a probable two, thus reducing the resistance of this contact. Open the jaw slightly and file off the burr left by the saw with a smooth file. The wires connecting the binding posts with the switch arm and jaw are short pieces of No. 16 bare copper and are carried down through the base and along a slot or groove cut in the under side to about the middle of the groove, where there should be a small hole,

say one made with a $\frac{1}{2}$-inch bit, $\frac{1}{4}$ inch deep, and there the two sections of the wire may be twisted together and soldered, the hole permitting the end of the soldering bit to reach the wires. These soldered joints *a* insure perfect, permanent contacts with less resistance than where mere surface contact is made. The swing joint at *f* is made by putting the switch blade between two washers, the upper one being slightly cupped by putting it on a hardwood block and striking it in the center with the ball of a ball peen hammer. This serves as a spring, and the blade works smoothly. Small brads *d, d* serve as stops. The knob *m* is made from hard wood $\frac{1}{2}$ inch in diameter, stained with india ink and

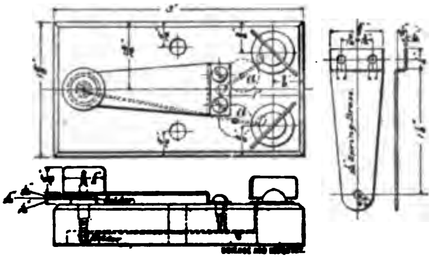


FIG. 6

varnished. Two holes *c, c* are provided for fastening the switch to the table. When all connections are made underneath, the wires and slot should be given two good coats of shellac. The battery wires are connected to posts 1 and 3, the instruments to 2 and 4.

As the bright brass parts are likely to tarnish readily, they should be lacquered. Finish each exposed part with fine emery cloth, warm slightly, and give a coat of brass lacquer except where electrical contact is to be made.

In some experiments it is necessary to change the direction of the current, and the pole-changing switch shown in Fig. 5 is used. Its construction and connections beneath the base are plainly shown in the sketch. The recesses *a, a, a* are for soldering the wire joints. The contact points *b, b, b, b* are made by filing round-head brass screws flat, after screwing them in place. Recesses *a' a' a' a'* are for soldering the wires to the screws. Use powdered rosin mixed with a little vaseline to solder these joints with, as acid will corrode them. The main circuit wires are attached to the posts marked (+) and (—), the instruments to the other two. Where two wires cross underneath the base, place two or three thicknesses of shellaced paper between them for insulation. Switch-blade stops are shown at *d, d.* Make the joints *f, f* as for the switch in Fig. 4. Moving the blades from one set of points to the other will reverse the direction of the current flowing through the instruments connected therewith.

In Fig. 6 is shown a spring key for making momentary contacts in certain experiments. Its construction is similar in detail to the two already described. Solder the knob contact screw to the spring as indicated, finish and lacquer.

(To be Continued)

THE DESIGN AND VALUE OF SEPARATORS

W. H. WAKEMAN

An Explanation of the Principles on Which These Useful Appliances Operate, and of Their Practical Value in Steam Plants

THE manufacture and sale of separators is a business that has grown rapidly during the past few years, denoting an appreciation of their merits

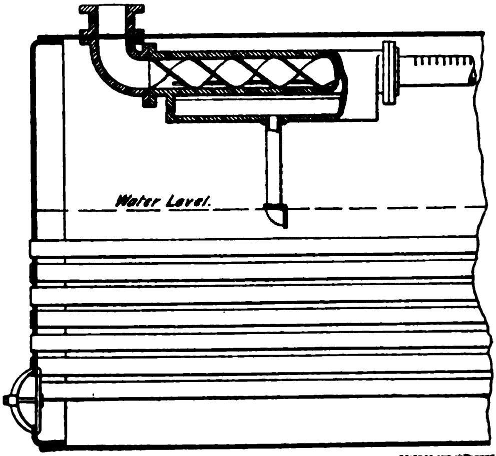


Fig. 1

by engineers and manufacturers wherever they have been given a fair trial. There are still many plants not equipped with them, although they are needed as much in these places as in others where they are used. As engineers seldom fail to recommend a good thing when they understand it, and as steam users are willing to pay for any thing that will earn money for them, this article is presented for the purpose of calling attention to this useful appliance.

Separators are used for two purposes; namely, to take water out of live steam and to remove cylinder oil from exhaust steam.

Some manufacturers do not see the necessity of a separator on their live steam pipe, as usually it is not very long and is well protected from the air by approved covering. The latter is valuable so far as it goes, but some boilers discharge wet steam, or, in other words, steam and water mixed, and the best pipe covering cannot cause water to be evaporated after it has left a boiler.

Water is detrimental to economy when mixed with steam, because it attracts heat from the steam and thus assists in promoting condensation. This is proved by experiments that have been made with superheated steam (which of course does not contain drops of water), for it was demonstrated that it does not give up its heat, and condense as readily as saturated, or even as quickly as wet steam.

Water is not wanted in an engine for two reasons—one of which is that it gives poor results when the plant is running, and the other is that there is

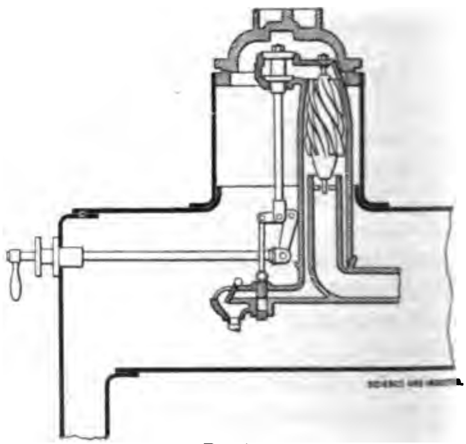


Fig. 2

great danger of it causing the plant to be shut down while a new cylinder is made for the engine. Therefore, a separator is a safeguard, especially if made large enough to hold a slug of water thrown over from the boiler, or that

results from a main steam pipe which does not all pitch towards the engine.

Even when a plant is properly designed and erected, water will rise with the steam, and unless the steam is superheated, these particles of water pass to the engine where they do no good, to say the least. This is the result in an ordinary plant, for according to the results of experiments, if steam rises from the disintegrating surface of a boiler at a higher rate than 3 feet per second, it carries water with it. In modern steam plants this rate is far exceeded, as it is not practical to design boilers large enough to keep the rate below this point.

Separators operate on two principles, as follows: If a mixture of steam, water, and oil, which is traveling rapidly in one direction, is suddenly changed to another, the water and oil will resist this change more than the pure steam, on account of their greater specific gravity, which gives them more momentum; consequently, these impurities are thrown violently to the

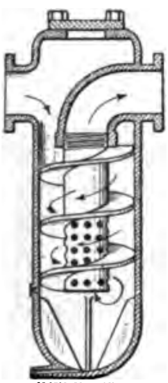


FIG. 3

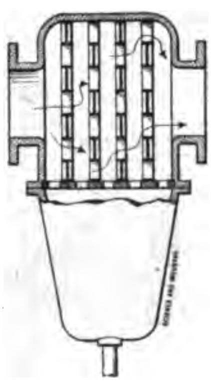


FIG. 4

outer part of the apparatus, causing the change of direction.

As water and oil are heavier than steam, they fall to the lowest point possible, by force of gravity, as soon as freed from the direct current of steam.

Having duly presented these principles we are ready to consider different means adopted for utilizing them in every-day practice in the steam plant.

Fig. 1 illustrates the Mosher separator applied inside of a tubular boiler.

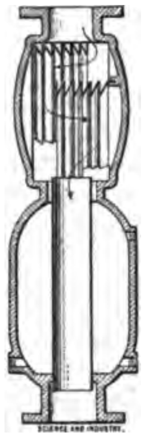


FIG. 5

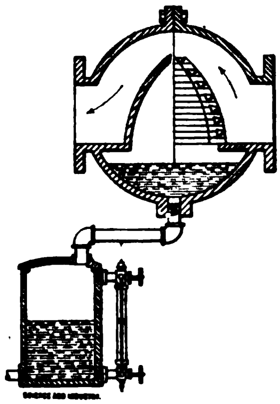


FIG. 6

Steam enters the dry pipe and travels in a straight line until it strikes the spiral plate, which quickly gives it a motion that develops centrifugal force, and throws the water outward. It is collected in a pocket and allowed to run back into the body of water.

Fig. 2 is another form of centrifugal separator, applied to the dome of a locomotive boiler.

This location of separator is only recommended for places where the steam pipe is very short, and there is good reason for carefully economizing room. Under all other conditions, the separator should be placed as near the engine as possible. The two separators above mentioned may be put near the engine if it is desired to do so.

In this connection it is well to remember that when water or oil is surrounded by steam not in motion, they obey the laws of gravitation the same as when subjected to atmospheric pressure only.

Fig. 3 shows the Keystone separator,

in which a somewhat different plan is adopted for giving the steam a spiral motion, to develop centrifugal force and throw out impurities.

The Lowdon separator, shown in Fig. 4, is a sample of the type in which

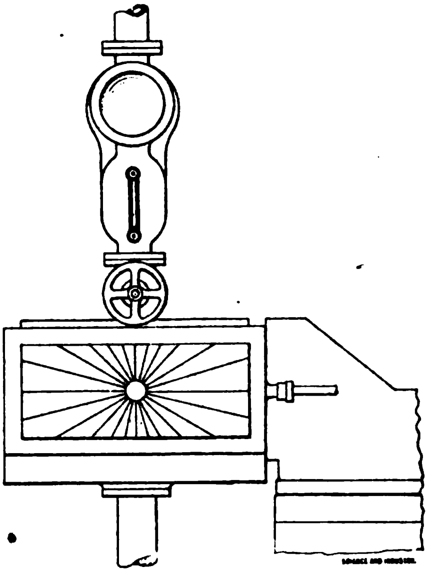


FIG. 7

the change of motion is executed by means of an apparatus that is not large, exclusive of the receiver provided to catch the water. Internally it consists of a series of plates in which the holes are located so as to completely break up the current of steam. Projecting collars are provided for these holes which prevent water from being drawn into the steam, after it is separated from it, and making its way by force of gravity to the receiver.

Fig. 5 illustrates the Zig Zag separator, in which the motion of the swiftly traveling current of steam is quickly changed by means of serrated surfaces placed at an acute angle to the flow of steam, thus utilizing centrifugal force to throw the water out of it, and as the steam passes over these serrated surfaces, separation becomes complete. While it is well to avoid using a separator that is too large, on account of its uncouth appearance, yet it is much more important to secure ample space for the steam to pass through, thus avoiding a reduction of pressure on this account. It is intended to present only those that are free from restricted passages, at this time, as lack of this important feature is a serious defect.

The Climax separator, shown in Fig. 6, does not reverse the motion of steam passing through it, but turns it nearly at right angles and causes it to pass over a serrated surface. This is a simple arrangement, which appears to work well in practice.

If a large pipe is used to convey steam from a battery of boilers to an engine room, and smaller pipes branch off and lead to several engines it simplifies matters, if one large separator is located at or near the end of the main pipe, but such an arrangement will not give the best results. When only one engine is in use, the steam will pass through the large separator at a low rate; hence, the operation is not rapid enough to do good work. Even

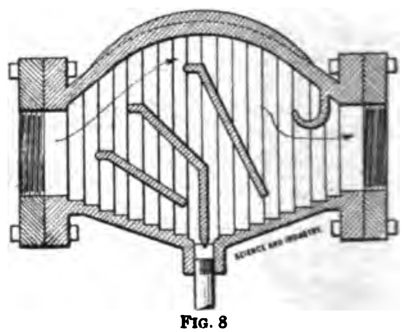


FIG. 8

when all the engines are running it is not a first-class plan, because there is a chance for water to collect, before the more distant engine is reached on account of condensation in the pipe. The neatest and best plan is illustrated

in Fig. 7, and it should be adopted wherever practical, as it is impossible for condensation to take place after steam leaves the separator.

Where steam is highly superheated it is difficult to properly lubricate the valves and piston, because the great heat partly or wholly burns the oil. When steam contains much moisture it interferes with lubrication, for when water flows along the bottom of a cylinder, oil will float on the surface of it, where it is evidently not wanted. As superheated steam represents one extreme, and very moist steam the other, it is well to avoid both by putting in a good separator, thus securing dry saturated steam, which gives good

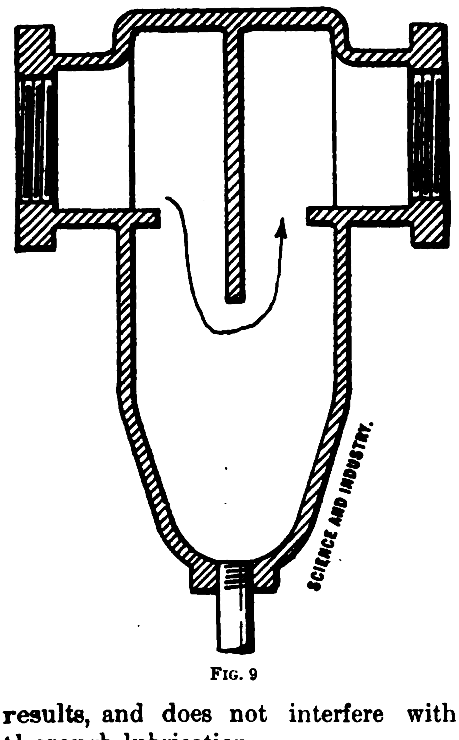


FIG. 9

results, and does not interfere with thorough lubrication.

Cylinders have undoubtedly been scored by means of water in them, on the surface of which cylinder oil has floated, for it does not require much water to do this. Especially is this true in the case of a large piston running in the low-pressure cylinder of a horizontal cross compound engine, without an outside bearing to support it. Condensation from the high-pressure cylinder and the receiver is carried to the large cylinder and causes the above mentioned trouble, which may be overcome by placing a separator between the receiver and the low-pressure cylinder.

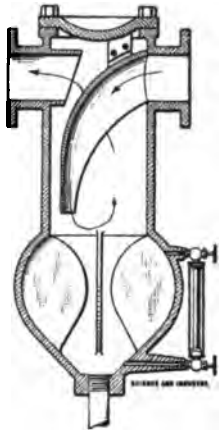


FIG. 10

There is one objection to this plan, for wherever it is adopted none of the oil used in the high-pressure cylinder can assist in lubricating the low pressure, because the separator will remove it. But it is nearly always considered necessary to provide a lubricator for this cylinder even when there is no separator in use; therefore, the above objection is not important.

The Reliance separator, shown in Fig. 8, deflects the steam only slightly from a direct course, but it is enough to answer the purpose in connection with the slanting plates which remove much of the water. Steam is turned against the corrugated roof, which assists in the separating operation, leaving only dry steam to pass to the engine.

After water or oil have been separated from steam, it becomes necessary to remove them from the direct current of steam, or else they will be taken up again and carried forward, where they are not wanted. If the separator is not large enough to provide a receiver for this purpose, a separate trap must

be furnished, and the two appliances connected by a pipe. In the former case a large amount of condensing surface is presented, while in the latter there is no large receptacle for a slug of water to drop directly into. Engineers must decide which objection is the least important in their particular case.

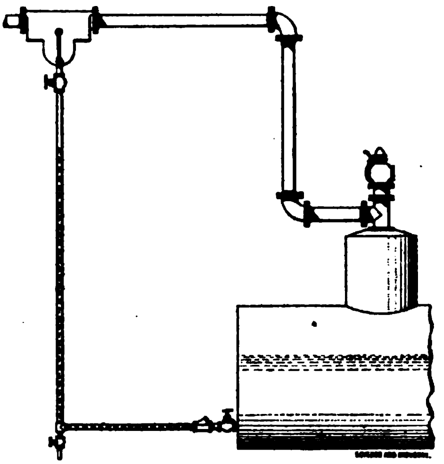


FIG. 11

Fig. 9 illustrates the Eclipse separator, the internal part of which consists of a single baffle plate placed at right angles to the flow of steam, which is given a sharp turn by this arrangement.

If such an appliance will purify steam, there certainly is no reason for adopting a more complicated device, but if water is separated from the steam by this means there seems to be nothing to prevent it from being taken up again, as it runs down the baffle plate and attempts to cross the current. In Fig. 10 the Lippincott separator is illustrated. Steam passing through this device is given a decided change of motion, which purifies it thoroughly.

Some separators are furnished with a drip valve when sent out from the factory, while others are not.

Where only a drip valve is furnished, it should never be closed while the appliance is in operation. Some men, who are not overcautious, attempt to keep this valve shut until the separator is full, and then open it in time to prevent any of the impurities from passing on, but they are sure to leave it closed too long.

The janitor of a certain building where the indirect system of heating was used, had a good separator on the exhaust pipe of his engine. He tried to keep the drip valve shut until the separator was full, and then open it, but he soon had the heating pipes coated with cylinder oil. Where no trap is provided it seems like a waste of steam to always have the drip valve wide open, but in such a case it may be partially closed, and the engineer can tell by watching the glass gauge, whether the separator is filling with water and oil, or not. If the waste is to be discharged to the sewer, a good trap should be provided.

In the case of a separator on the main steam pipe of a plant, the resulting water may be returned to the boiler, as illustrated in Fig. 11, provided the separator is located high enough to permit the water to run back. It must discharge below the

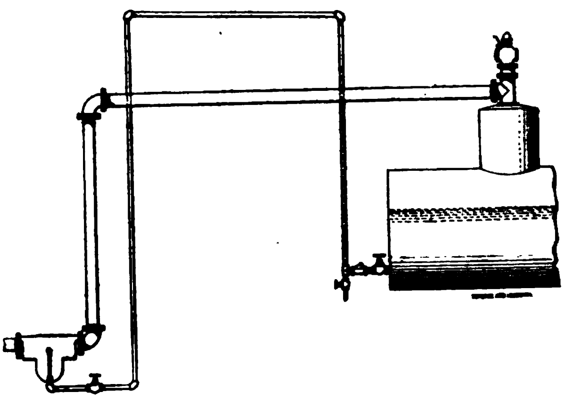


FIG. 12

water-line of boiler. Do not fail to put a good check-valve on the return pipe. If the separator is too low for this plan, a steam loop may be provided, as shown in Fig. 12.

The Hine eliminator is illustrated in Fig. 13. The principle involved in its construction is that of corrugations at all points where the steam impinges, washing it, so to speak. They are constructed and placed at such angles that the water and oil are carried off in a different direction from the course of the steam, and do not come in contact with the steam again.

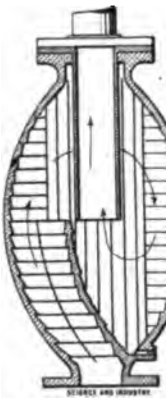


FIG. 13

I have used one of these for nearly eight years, to take oil out of exhaust steam, and it has proved an unqualified success. The steam is turned sharply in its course, throwing oil and water outward to the corrugated surfaces, which assist in separating them from the steam and keeping them separate. The drip valve is kept open about one turn of the wheel while steam is used for heating, and is opened wide at other times. It is also opened wide for a few minutes, occasionally when under pressure, in order to prevent grease from accumulating in the drip pipe.

By adopting this device, the exhaust steam from one engine and two pumps is made available for heating purposes, and the resulting water is returned to the boilers. This plan not only saves heat that would otherwise be wasted, but provides distilled water, which is free from scale-making impurities.

In the summer time when heat is not wanted, it is useful because it takes all of the water and oil out of the exhaust steam, thus preventing damage to roofs, etc.

It is necessary to connect some separators so that steam will pass through them in a given direction, or else they will not work properly, owing to their internal design and construction.

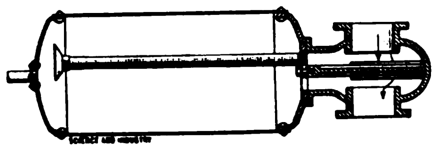


FIG. 14

The Cockrane separator, shown in Fig. 14, belongs to this class. It has an arrow cast on the outside of it to show which way the steam must travel, and this should be taken into account. In other kinds the words "inlet" and "outlet" are used to show the engineer how the device should be connected. The Stratton separator, illustrated in Fig. 15, also belongs to this class.

Some separators are made so that steam may enter at either end, and leave at the other, as both sides are alike. The Hoppes separator, shown in Fig. 16, is a sample of this class. There is no special advantage gained by this arrangement, except that it is impossible for a stupid steam fitter to connect it improperly.

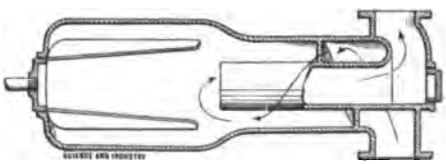


FIG. 15

It is not a difficult matter to calculate the amount of water that will result from condensation in a steam pipe under given conditions, as experiments have been carefully made and the results reported. It appears that

$\frac{1}{420}$ pound of steam is condensed per hour for each square foot of pipe surface, for each degree difference of temperature between the steam and

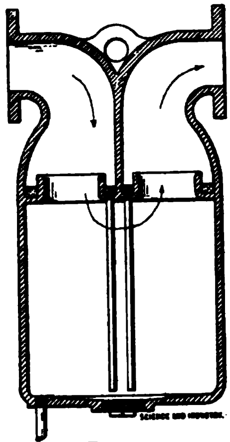


FIG. 16

outside air, therefore it is only necessary to multiply the number of square feet of pipe surface, by the difference in temperature and divide the product by 420. The quotient will be in pounds per hour.

When this calculation is made it will show that much more steam is condensed than was thought possible before the matter was investigated. This rule applies to ordinary pipe,

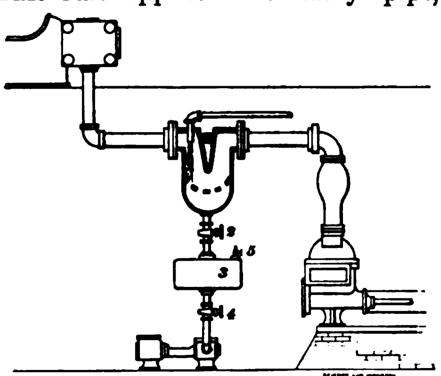


FIG. 17

uncovered, in still air. Where it is exposed to drafts, it will be from 2 to 5 times the above, according to the speed at which the air circulates.

The condensation is greater as the pressure is increased, and this fact is recognized by the rule.

Fig. 17 shows the Austin separator as used in connection with a condensing engine. The vacuum which exists in the exhaust pipe interferes with the ordinary action of a separator, hence it is found necessary to spray water into the steam as it enters the appliance. This provides the moisture necessary to separate the drops of oil, as when the oil and water are mixed the specific gravity of the mixture is great enough to cause it to fall in the usual way. The valve *2* is opened, and *4* closed, thus allowing water and oil to collect

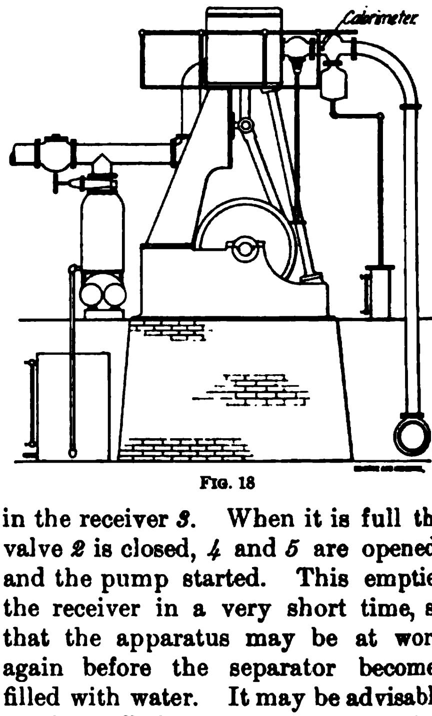


FIG. 18

in the receiver *3*. When it is full the valve *2* is closed, *4* and *5* are opened, and the pump started. This empties the receiver in a very short time, so that the apparatus may be at work again before the separator becomes filled with water. It may be advisable to shut off the water while pumping out the receiver. Water used to supply this spray is not wasted, because it condenses some of the steam, thus leaving less for the air pump to dispose of. The small pump shown is not an absolute necessity, but is

provided in order to empty the receiver in less time than would be required for the water to run out by gravity. It may prove convenient where the condensing apparatus is low down, to use this pump to elevate the water coming from the receiver, as frequently such apparatus is below the sewer.

Fig. 18 shows a plan for connecting a separator to a vertical engine, just in advance of the throttle valve. A small tank is used to hold the water that comes from the separator, and by this means it is an easy matter to determine just how much water would otherwise go to the engine. A calorimeter determines the quality of steam after it has passed the separator.

Separators are used in refrigerating plants to remove oil from ammonia gas, in order to prevent it from coating the internal surfaces and reducing the efficiency of the system.

They may also be used to remove moisture from compressed air when it is used to operate machinery.

GRATE BARS AND STATIONARY GRATES

R. T. STROHM

FROM the hour that the fire is started in the furnace and the boiler put into active service as a steam generator, it tends to deteriorate. In order to maintain the efficiency of the apparatus, as well as the greatest attainable degree of safety, it is necessary to subject the boiler to frequent inspection, and it will be found, as a usual thing, that the first repairs to be made will be in the furnace, either to the grate or to the lining.

There are many reasons why this is the case. Those parts of the boiler setting which bound the furnace and the combustion chamber are continually subjected to a high degree of heat, which, however, is far from constant in its intensity. The shell of the boiler, having water on one side, cannot become very much hotter than this water, even on the fire-side, assuming that the plates are kept reasonably free from sludge and scale. Not so the furnace lining and the grate. They are quite exposed to the intense heat; the former to the heat of the burning gases and the radiant heat from the bed of incandescent coal; and the latter to the heat conducted to it through the fuel bed.

The necessity of repairing the grate at frequent intervals makes it essential that it shall be so constructed that it shall admit of the easy removal of the broken or worn-out part, as well as the rapid and ready substitution of the new. For this reason, the usual form of stationary grate is composed of a number of similar separate sections, each known as a grate bar. These are of various designs and shapes, according to the form of the furnace and the nature of the fuel to be used.

The main purpose of the grate is to support the fuel. If this were its only purpose, however, it could be made solid. But in order to insure perfect combustion it is necessary to admit air to the furnace through the fuel, and consequently the grate must be perforated with numerous holes or apertures which will permit of this flow of air from the ash-pit through the fire. Further than this, it is necessary to keep a clean fire to produce the best results from a given fuel. If the grate were solid, the refuse would collect rapidly in large quantities, and the cleaning of the fire would be much more difficult than it now is. But owing to the openings in the grate, a

large amount of the finer portions of the refuse falls into the ash-pit, whence it may be easily removed as desired.

While the grate openings should allow the ashes to pass through, they

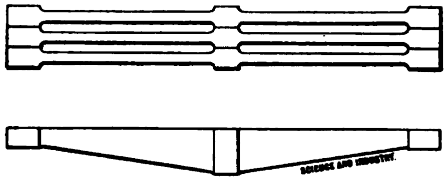


FIG. 1

must not be so large as to allow any of the unburned fuel to drop into the ash-pit. This means that the size of the opening in the grate must be regulated according to the size of the particles of fuel to be burned upon it. These openings in the smallest sizes usually run as low as one-fourth of an inch, although, for the burning of the very smallest varieties of anthracite, such as screenings and dust, grates have been specially designed and built containing air spaces of but three-sixteenths of an inch in width.

The most ordinary type of grate consists of a series of cast-iron bars laid side by side, each running from the front to the rear of the furnace in the direction of the longitudinal axis of the boiler. The reason for putting them in in this manner is that they are more easily cleaned in this position than if they were arranged to lie parallel to the boiler front. For in the latter case the air spaces would run from side to side of the furnace and so be liable to catch the edge of the slice bar.

Two forms of the simplest type of grate bar are shown in Figs. 1 and 2. The first consists of a narrow cast-iron plate having a depth at its middle equal to about twice the depth at its ends. At the center and at the extremities the bar is widened at both sides so as to form lugs of such width that when the bars are placed side by side, as shown, the lugs meet, leaving air spaces between the bars equal to or greater than the thickness of the bar itself. This bar is symmetrical, having its ends alike, so that it makes no difference which end is placed at the front of the furnace. The size of the air space in grates of this kind is fixed by the width of the lugs at the ends and center of the bars.

The form of grate bar shown in Fig. 2 is almost as plain and simple as the previous one. It is known as the interlocking bar. As may be seen, each bar is provided on both sides with several short lugs, symmetrically placed, which serve to keep the bars apart when they are placed side by side, thus forming the air spaces. These lugs answer another purpose also. They provide an interlocking arrangement of each bar with its neighboring bars, preventing either vertical or longitudinal motion. In building up a grate composed of interlocking bars, the work is begun at the side of the furnace and carried toward the middle. A bar like No. 1 is placed next the side wall and then a bar like No. 2 fits into it, being followed by another No. 1 and so on, alternating until the middle of the furnace is reached, a No. 2 bar

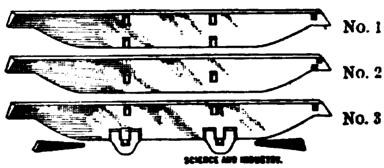


FIG. 2

being the last one placed. The same operation is repeated from the opposite side of the furnace. The result is that two No. 2 bars are left facing each other at the middle of the grate. Into the

space between them is now fitted a bar like No. 3, and through the lugs on the under side of this bar are driven the iron wedges so that they project on either side under the adjoining bars. This effectively locks the entire grate, since no bars can be taken out until the middle bar is removed.

One of the prime requisites of the cast-iron grate bar is that it shall be easily and cheaply made in the foundry. In this respect, the two types thus far mentioned are superior to any others, since they consist of plain bars which require little skill in molding and are not liable to cause any trouble in casting.

Again, it is necessary that the bar shall be of such shape and section that it shall not warp under the effect of the heat in the furnace. For it must be evident that the top of the grate, on which the incandescent fuel lies, must be considerably hotter than the lower edge of the bar near the ash-pit. The tendency of this inequality in temperature is to bend the bar upward in the middle, or toward the sides, in case vertical motion is impossible. A good bar must be able to resist such forces

For this reason most bars are made with one or two vertical webs, deeper at the middle than at the ends, since the bar may be considered as a beam uniformly loaded and supported at the ends, which causes the greatest bending moment to occur at the middle. Now, it would be very easy to prevent warping or bending of any shape of grate bar by simply making it stronger in those sections subject to the greatest stress. But in doing so, the air space would likely be sacrificed to some extent, which is undesirable. In order to give sufficient air for good combustion the grate should have at least 50 per cent. air space. With the forms of bar shown in Figs. 1 and 2, it is very difficult to obtain much more than 50 per cent. of opening. The width of the grate bar must be lessened as the width of the air space is increased, and when the latter is large, the satisfactory casting of the plain bar becomes difficult because of its thinness, while its liability to warp or burn out is much increased.

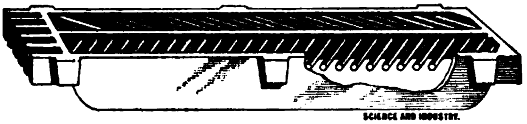


FIG. 4

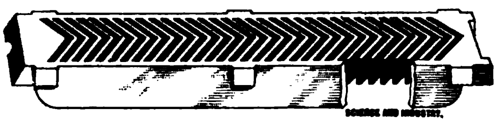


FIG. 3

Owing to the fact that the different kinds of coal require different amounts of air space to obtain satisfactory combustion, it has been found necessary to build grates having various percentages of opening to accommodate the several grades of coal. The patterns of grate bars best suited to the different conditions are approximately as follows:

$\frac{1}{4}$-inch opening and $\frac{5}{16}$-inch iron for bird's-eye coal.
$\frac{3}{8}$-inch opening and $\frac{3}{8}$-inch iron for buckwheat coal.
$\frac{1}{2}$-inch opening and $\frac{1}{2}$-inch iron for pea or nut coal.
$\frac{5}{8}$-inch opening and $\frac{1}{2}$-inch iron for stove coal.
$\frac{3}{4}$-inch opening and $\frac{1}{2}$-inch iron for egg coal.
$\frac{7}{8}$-inch opening and $\frac{1}{2}$-inch iron for broken coal.
1-inch opening and $\frac{1}{2}$-inch iron for lump coal.

The above list refers only to anthracite fuels. For bituminous coal the grate bars should have $\frac{1}{2}$-inch iron and $\frac{1}{2}$-inch, $\frac{5}{8}$-inch, or $\frac{3}{4}$-inch air spaces, according to the fineness or coarseness of the fuel, the smallest opening being used for the finest coal.

In case the boiler is to be used in or about a sawmill or wood-working establishment, it may be desirable to use the refuse from them for firing. In

such cases the size of grates would be:

$\frac{1}{4}$-inch or $\frac{3}{8}$-inch opening and $\frac{3}{8}$-inch iron for sawdust.
$\frac{3}{8}$-inch or $\frac{1}{2}$-inch opening and $\frac{1}{2}$-inch iron for shavings.

To obtain a grate which should have small individual air spaces and yet give a total opening of at least 50 per cent.,

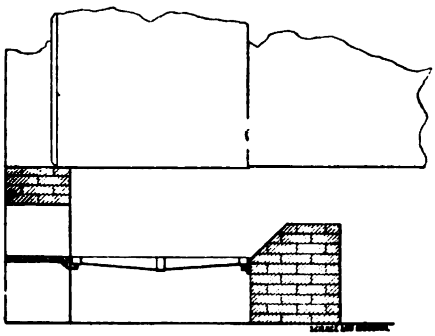


FIG. 5

the herring-bone grate, shown in Fig. 3, was designed. It consists of two parallel longitudinal webs joined at regular intervals by shorter V-shaped webs, the separate bars being held apart by lugs cast on the outside. This has proved to be a popular grate bar, and has given such excellent results that it has been widely adopted. Another form of this grate bar is shown in Fig. 4. It consists of three parallel webs united by short wrought-iron rods spaced at the required distance to give the desired air openings. The advantages claimed are, a greater percentage of air space, better contact of air with the fire, and less liability of clogging by clinker.

The grate bar must be designed to allow clinker and ashes to drop through easily. To accomplish this, the iron webs are all made wedge-shaped, with the thin ends pointing toward the ash-pit. This makes the air space considerably wider at the bottom than at the top of the grate, so that if refuse once gets through the space and below the level of the grate surface, it will be certain to fall into the ash-pit. Reference to Figs. 2 and 3 will show the tapering sections of the webs.

One of the essential requirements of a good stationary grate is that it shall present a comparatively flat surface. This is necessary in order that the slice bar and other firing tools may be easily used. This in turn requires that the bars of which the grate is built shall be uniform in depth and carefully placed, for any unevenness adds to the labor of stoking, and renders the grate more liable to damage.

The top of the grate bar, under the effect of the fire, may come to a red heat. At such a temperature the iron is much softer and weaker than when cool, and so it becomes necessary to make the bar of considerable depth to resist the bending moment due to its own weight and the weight of the fuel. The webs thus formed act in a two-fold capacity. First, they strengthen the section; and second, they form surfaces against which the air-currents impinge and are heated, the bar being correspondingly cooled, both of which are desirable ends.

As a usual thing, the space between the grate surface and the boiler shell is

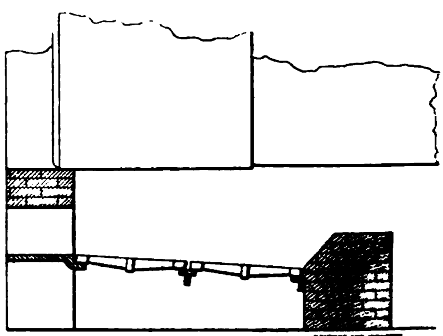


FIG. 6

limited, and therefore sectional grates must be made of units of such size and weight as to be conveniently handled in the operation of repairing. If the grate is comparatively short, it is built

up of a single row of bars laid side by side, their ends resting upon bearing bars extending across the furnace at the front and near the bridge wall, as illustrated in Fig. 5. Where the grate is very long, however, a third bearing bar is placed at the middle of the furnace and two rows of short bars used, as shown in Fig. 6. The end bearing bars often consist of pieces of angle iron extending entirely across the furnace and fixed into the side walls. The front bearing bar, however, may be an L-shaped part of the casting forming the dead plate. The middle bearing bar is made either rectangular or T-shaped in section, and, like the others, is usually of wrought iron.

In installing a grate, care must be taken not to fit the sections together too tightly. Cast-iron expands under the influence of heat, and therefore it is necessary to allow for this expansion by leaving a space of three-fourths of an inch or so at each side, as well as a corresponding amount at the ends to allow for longitudinal expansion. With long grates, it is customary to give them a pitch or slant toward the bridge wall, in order to facilitate firing, making the end at the bridge about three inches lower than that at the fire-door.

The most powerful factor contributing to the failure of grate bars is the heat of the furnace. Through its action the bar is warped, softened, and reduced in strength. Allowing hot ashes and clinker to pile up in the ash-pit close to the bottom of the grate also causes rapid deterioration of the latter, while careless or unnecessarily rough handling of the firing tools is no doubt responsible for many breakages.

Considering that the grate bar must be subject to intense heat, it must be evident that a judicious selection of the material of the bar will have a great deal to do with its strength and its lasting qualities. For cast-iron grate bars, a light-gray iron containing little or no phosphorus is desirable, since it possesses a high fusing point and does not soften readily.

Wrought-iron grates have been tried, but they are more quickly softened by the heat and are not nearly as stiff as cast-iron bars, so that solid wrought-iron grates have not proven successful. In the case of the down-draft furnace, however, hollow wrought-iron grates have been found quite valuable, the grate bars being made of wrought-iron pipes so connected to headers and to the boiler as to have a rapid water circulation, the water acting as a cooling agent. The same system is employed in furnaces using preheated air, since in such a case the air-currents cannot be depended upon to cool the grate.

SUPERHEATED STEAM

WALTER W. EDWARDS

STEAM may be classified, according to the amount of heat it contains, under two heads: saturated steam and superheated steam. Saturated steam is still further divided into wet saturated steam and dry saturated steam. This subclassification, like the first, depends on the amount of heat that is contained in the steam. If the steam contains just sufficient heat to maintain it in the form of vapor at a given pressure, it is called *dry* saturated steam, while if there is insufficient heat to completely vaporize every particle of water, it is called *wet* saturated steam. The properties, such as temperature, weight, etc., of dry and saturated steam are tabulated in what are called Steam Tables, which constitute an indispensable aid to almost every investigation relating to steam. The term "saturated" refers to saturation with *heat*, not with moisture.

The energy that is consumed in forcing the molecules of water apart when water is vaporized, disappears as heat but reappears in the form of work. This energy, since the molecules are held apart against the force of cohesion and external resistance, is potential energy, but in the form of heat it was kinetic energy. The amount of heat that is thus consumed is called the latent heat of steam.

The amount of latent heat that is present in a mass of wet steam, expressed as a percentage of the total latent heat present in an equal weight of dry and saturated steam, is termed its quality. The quality of dry and saturated steam is always unity; the quality of wet and saturated steam is always less than unity, while the quality of superheated steam is always greater than unity. The amount of superheat is always expressed, however, in degrees rather than in a percentage of the latent heat. When steam is further heated after all the water has been vaporized, it changes its nature in many respects, and is termed *superheated steam.*

Among other changes that it undergoes, may be mentioned the fact that while it is water or saturated steam, its specific heat is 1, but when it becomes superheated, its specific heat is .48, with constant pressure, and .346 with constant volume. The results of experiments recently conducted by Prof. Bach, of the Technical High School of Stuttgart, Germany, seem to indicate that the correct value of the specific heat of superheated steam at constant pressure is very close to .60.

Superheated steam was used to a greater or less extent in the decade preceding 1870 with gratifying results, but with the advent of the compound engine and higher steam pressures, it was found that all the gain and more, that was effected by superheating, was obtained in an easier manner. The higher pressures meant higher temperatures for the saturated steam, and when this was superheated, the temperatures passed beyond the point at which it was possible to utilize the steam without injury to the engine. Owing to defective lubrication incident to the use of highly heated steam, the cylinders, valves, and valve seats were scored and cut. The lubricants of twenty-five years ago were of animal or vegetable origin, and when subjected to the temperature of superheated steam, were burnt, and the residue formed a powder which, in a short time played havoc with the moving parts of the engine. The soft packing

used around the valve stems and piston rods was also poorly adapted to withstand the higher temperatures and soon gave trouble by charring and leaking.

Another practical difficulty was the increased amount of expansion of the cylinder due to the increase in the temperature of the steam. The greatest expansion, of course, always came where the metal was thickest, and thus resulted in a distortion of the cylinder and sometimes in its actual destruction.

In the boiler room the principal difficulty seems to have been with the superheater itself. Owing to the low thermal conductivity of superheated steam, the tubes of the superheater were frequently burnt out when exposed to the hot gases of combustion. Difficulty was also experienced in keeping the joints tight.

These difficulties have gradually been overcome, however, and there seems to be every prospect of the extensive adoption of superheating. The high steam pressures of today have demanded and obtained a grade of oil that superheating does not affect. Metallic packing has largely taken the place of soft packing, and improvements in the distribution of the metal of the cylinder have prepared the way for superheated steam, so that we find the engine of today much more suited to its use than was the engine of the time when superheating was abandoned.

The principal gain by the use of superheated steam is found in the prevention of initial cylinder condensation. Since the temperature of saturated steam depends on its pressure, it follows that when the steam expands to the pressure of the exhaust, and performs work during expansion, its temperature must correspond to the pressure of the exhaust. This in turn cools the cylinder walls so that when admission takes place, the fresh steam must give up part of its heat to raise the temperature of the cylinder walls. This results in a condensation of about 25 per cent. of the entire weight of steam that the engine uses.

The loss from this source has been recognized for years and the efforts employed for its prevention have been directed along four separate and distinct lines, which may be summarized as follows:

(*a*) Heating the cylinder by means of a jacket of live steam from the boiler; (*b*) early closure of the exhaust so as to fill the clearance spaces with steam of boiler pressure by means of compression; (*c*) increasing the number of cylinders so that the range of temperature in any one cylinder might be reduced to a minimum; (*d*) raising the temperature of the entering steam above that due to its pressure as in superheating.

The use of a jacket involves a complicated and expensive form of cylinder, and since it tends to heat the exhaust as well as the entering steam, it is wasteful of heat. Its value is also impaired because it heats only that small portion of the steam that is in direct contact with the cylinder walls.

If compression is carried to full boiler pressure, there is a consequent loss of power; at best it only results in the prevention of condensation in the clearance spaces, while what it is designed to prevent continues to occur up to and beyond the point of cut-off.

Multiplicity of cylinders has its objection in additional weight, increased friction, greater cost of supervision, and the fact that the low-pressure cylinder is always open to the same losses to which the single cylinder is subject.

The use of superheated steam is attended by none of these disadvantages. The superheat being distributed evenly through the mass of steam in the cylinder, its efficiency in maintaining the steam in a dry condition is greatly superior to the jacket. It lasts until after the point of cut-off instead of merely being effective on the steam in the clearance spaces, as is the case with compression. It reduces the advantages gained by building engines with three or more cylinders, and since its density is much less than saturated steam, there is a corresponding increase in the vacuum. The size, weight, and power required for the operation of the condensing machinery are also considerably reduced.

Superheated steam has a lower thermal conductivity than saturated steam, and consequently the loss from heat radiation is less. The friction in passing through pipes is also much reduced.

It has been proven by experiment that about 8 degrees of superheat in the entering steam is necessary for the prevention of each 1 per cent. of moisture in the cylinder at cut-off when using saturated steam. If we take the specific heat of superheated steam of constant pressure to be .48, it follows that a rise of 8 degrees in the temperature above the normal temperature of saturated steam of the same pressure represents the expenditure of $.48 \times 8 = 3.84$ B. T. U. Assuming the initial condensation of the entering steam to amount to 20 per cent., 3.84 B. T. U. $\times\ 20 = 76.8$ B. T. U. must be added in the form of superheat to insure dry steam in the cylinder at cut-off.

It takes, approximately, 1,100 B. T. U. to convert a pound of feedwater at ordinary temperature into steam at usual pressure. By the addition of 76.8 B. T. U. in the form of superheat, we have increased the expenditure of heat by about 7 per cent., and decreased the expenditure of steam by 20 per cent., which represents a saving of 220 B. T. U. In other words, 76.8 B. T. U. *rightly expended* prevent a loss of nearly three times as much heat. Since in many superheaters the additional heat is taken from the waste gases, there is not any increase in the expenditure of fuel, and the saving in heat is a clear gain. It should be borne in mind that superheating does not change the values of the quantities involved in $\frac{T_1 - T_2}{T_1}$, which is the formula for theoretical thermal efficiency, but only enables the engineer to more nearly approach the value $\frac{T_1 - T_2}{T_1}$ as a limit.

The proposition of admitting superheated steam to the receivers of a multiple-cylinder engine with the idea of drying the steam before it enters the next cylinder is not feasible because the amount of extra heat carried by the superheat would reevaporate only a very small portion of the condensed steam. It takes, approximately, 1,000 B. T. U. to convert 1 pound of the condensed steam into vapor again. The amount of extra heat a pound of steam having 100 degrees of superheat carries is $100 \times .48 = 48$ B. T. U. It would, therefore, require 1,000 B. T. U. $\div$ 48 $= 21$ pounds of superheated steam to reevaporate each pound of steam that is condensed. An amount as great as this is wholly out of the question.

Superheating between the cylinders is accomplished by fitting a tubular reheater between the cylinders and allowing live steam from the boiler to pass around the steam in the receiver, but not to mix with it. This is an efficient means of reheating, and adds to the amount of work done per pound of steam in the low-pressure cylinder. It is in fact a steam jacket for the receiver.

With the temperatures of superheated steam that are in use at present, it is impossible to have superheated steam in more than the first cylinder. The steam remains superheated during only a part of the stroke in the high-pressure cylinder, it being very unusual to find it superheated up to the point of release.

Superheating should not be regarded as a means of carrying more heat to an engine, but only as a preventative of waste through condensation. For this reason a boiler used for heating purposes should not be fitted with a superheater unless the steam is to be carried a long distance before its heating effects are to be utilized. Greater gain would be obtained by using the superheating surface as additional heating surface for the evaporation of water. In central heating plants, where the steam is to be carried a long distance before being used, the peculiar properties of superheated steam are again of the utmost utility. Condensation, that always causes a loss of pressure from the diminution of volume, leaking joints, and danger from water in the pipes, is to a great extent avoided. In the same manner as in the engine cylinder, the superheat maintains the steam in a dry condition long after it would have been partially condensed had not superheating been resorted to. Friction in the pipes, as has been pointed out, is less than with saturated steam, and consequently the loss from this source is less when carried a long distance from the boilers.

Present indications all point to the steam turbine as the form of engine in which superheated steam will find its field of greatest usefulness. Its greatest disadvantage when used with a reciprocating engine is its effect on lubrication; but with the steam turbine this disadvantage ceases altogether, as there is no lubricant present to be burned. One of the greatest losses of efficiency in the steam turbine is the friction between the wheel and casing caused by a film of water clinging to the inside of the casing and retarding the vanes or arms of the revolving disk. This is analogous to the resistance caused by the film of water next to the hull of a moving ship, and the loss due to this cause is precisely the same thing as the loss so well known to marine engineers as "skin resistance." Another cause of loss of power in a turbine due to wet steam is drops of water falling on the disk, obtaining a high velocity, flying off again to the casing, carrying their load of energy with them, and then dropping back again on to the disk only to again fly off with their load of useful power. Dr. R. H. Thurston computes the loss due to this cause to be 1 horsepower for every 275 drops that leave the disk of a turbine making 200,000 revolutions per minute. The diameter of the disk used in his experiments was 10″. These losses, due to moisture in the steam, are entirely obviated by the use of superheated steam, and there seems to be no practical limit to the degree of superheat that a turbine engine can use. With a reciprocating engine the limit to the degree of superheat is found to be set by the engine cylinders, while with the steam turbine the limit is set by the boiler and superheater.

The design of superheaters does not come within the scope of this article. Superheaters to be a success should have means of being readily cut out of service or of being flooded with water when it becomes undesirable from any cause to use them. They should be so constructed that there are no joints exposed to the fire. The tubes should be so arranged that there is ample provision for expansion, and, lastly, they should be so placed that repairs can be easily and quickly made.

WATER RHEOSTATS FOR TESTING PURPOSES

F. H. DOANE

DESCRIPTION—VARIETY OF USES—CONNECTIONS

THERE are few pieces of apparatus in an electrical shop that can be put to more varied and useful work than a water rheostat. With this form of rheostat a wide range of resistance may be had, and the device may be of very simple and cheap construction. It is almost impossible to damage the water rheostat from overload or rough use, unless the box itself is smashed, as the resistance consists of water and the plates are made of iron.

Water rheostats are made in a number of shapes and sizes to fit the work for which they are designed. In an electrical shop, where a large number of sizes of motors and small dynamos

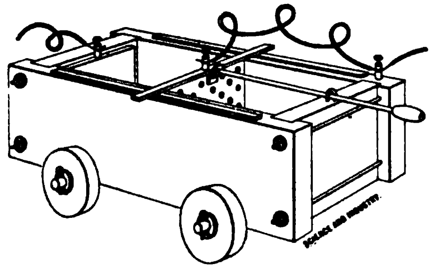


FIG. 1

are being tested, a water rheostat of a size to take care of the largest dynamo or motor to be tested, and mounted on wheels so as to be portable, will be found to be of great service. Such a device may be constructed at a small expense.

The wooden box for holding the water is in the shape of a rectangle and about 1 foot deep inside. For ordinary shop work with small motors or dynamos the box may be made 4 feet long and 16 inches wide, outside dimensions. It should be constructed of 2-inch smooth boards and carefully put together so that it will not leak water. Fig. 1 shows the general appearance of the box. Along the tops of the long sides fasten on strips of brass, or iron, on which the bearings of the movable plate may slide.

A fixed iron plate is provided at one end of the box. Care should be taken that this plate does not touch the strips on the sides of the box. This plate should be about $\frac{3}{8}$ inch thick and 1 foot long by 1 foot wide. The plate is securely fastened to one inside end of the box. A large binding post is mounted either directly on the plate, or on the adjacent top of the end piece of the box and connected to the plate.

The movable plate is 11 inches long by 11 inches wide and is $\frac{3}{8}$ inches thick. A number of holes should be bored through the plate so that it may be easily moved through the water. On the top of the plate screw a piece of iron 16 inches long by 1 inch wide and $\frac{1}{2}$ inch thick. This forms the bearings of the plate as the ends of the top strip rest on the sides of the box. A binding post is placed on the movable plate and is connected by means of a flexible cable to a terminal binding post on the corner of the box.

A small piece of gas pipe, fastened at one end to the movable plate and provided at the other end with a wooden handle, serves to move the movable plate toward or away from the fixed plate. The handle is prevented from moving in any direction but forward and back, by means of a staple over the pipe, which is driven in the top of one end piece of the box.

The box is mounted on four wheels so that it may be moved from place to place in the shop

as occasion demands. When preparing the water rheostat for use, fill the box three-quarters full of water. Then put in about a handful of rock salt or washing soda. The more salt or soda put in the box, the less the resistance of the rheostat will be from plate to plate. When the plates are at opposite ends of the box the total resistance of the rheostat is in circuit. As the movable plate is brought nearer the fixed plate the resistance is gradually cut out until the plates touch each other, when the resistance of the rheostat is cut out. A short-circuiting switch may be provided so that when the plates are close together the switch may be thrown in, which connects one terminal binding post to the other terminal binding post and short circuits the rheostat. The switch should be mounted on the end of the box near the fixed plate. Care should be taken that the switch is not closed when the rheostat is first connected in circuit, as all of the resistance would be cut out.

When used as a starting rheostat, with a shunt-wound motor, the general connections should be as shown in Fig. 2, when *Sw* is the motor switch, *Sh* the shunt field coil of the motor, *A* the armature of the motor, and *R* the water rheostat. It will be noted that the shunt field is connected directly across the line and that the water rheostat is connected in series with the armature across the line. By moving the movable plate in the water rheostat toward the fixed plate, the resistance of the rheostat is cut out and the motor brought gradually up to speed.

When the rheostat is to be used as a load for a small compound-wound dynamo under test, the connections should be made as indicated in Fig. 3. The series field coil is indicated by the letters *Se*, and *F* represents the field rheostat. The water rheostat *R* is connected across the terminals of the dynamo, and the load on the machine varied by means of moving the plate in the rheostat. The ammeter *Am* is used to measure the current flowing through the rheostat.

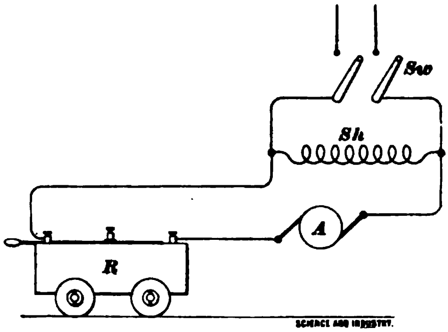


FIG. 2

Another form of water rheostat that may be used for testing dynamos is illustrated by Fig. 4. A substantial barrel is used to contain the water. The fixed plate is at the bottom of the barrel. It is connected to a binding post at the top of the barrel by a rubber-insulated wire, and it is well to further protect the wire by running it in a hard-rubber tube. There are a number of ways of adjusting the movable ring or plate. The top plate or ring, which is provided with a rod, may be lifted by means of a rope passing over a pulley and fastened to the top of the rod. A rack and pinion may be used as

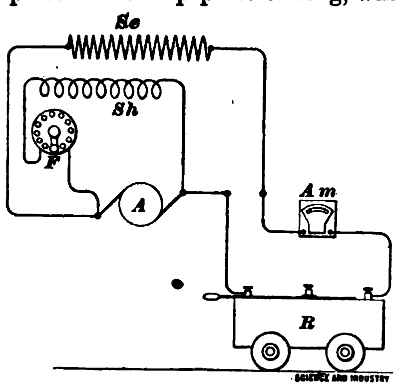


FIG. 3

illustrated in Fig. 4. There must be enough friction in the bearings of the pinion so that the plate cannot fall when the hand is taken away from the turning crank, or else a simple friction brake may be provided to hold the top plate in place. The handle on the pinion shaft should be made of wood to insulate it from the live parts of the apparatus. A system of levers may be used to adjust the movable plate. If a plate is used, several holes should be bored in it so that it will move through the water easily. A cast-iron ring of considerable surface area is suitable to use in place of the plate.

For testing large dynamos or for station testing, water rheostats are made in the form of huge tanks several feet high. The plates are made of iron, and one plate may be fixed while the other is movable. Where a body of water is very near the station, a large water rheostat can be made by placing a plate a few feet under the surface of the water and arranging another plate so that it can be lowered toward the fixed plate, or hoisted away from the fixed plate. In place of iron plates, large coils of lead pipe may be used.

The water becomes hot in the water rheostat as current passes through it, and this decreases its resistance. The salt takes some time to become dissolved and distributed, so that the resistance of a water rheostat is quite variable, especially at first. When using the rheostat, as a load for a dynamo, the ammeter in series with the rheostat should be carefully watched to see that the decreasing resistance of the rheostat does not cause an overload.

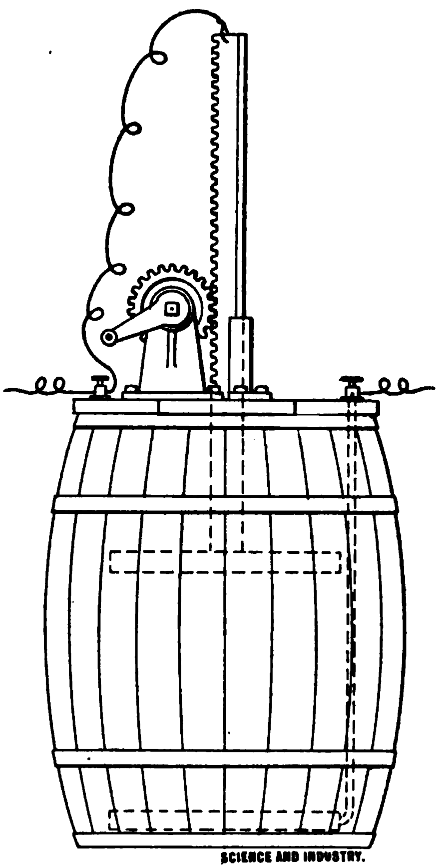


FIG. 4

A form of rheostat sometimes used for providing a constant load consists of a number of coils of bare iron or German-silver wire connected to each other in series, or in multiple, and immersed in a barrel of water. Terminals from the coils are led to a terminal board on the top of the barrel. The coils should be separated by light wooden partitions open at top and bottom. A small stream of water should be allowed to run into the barrel during the test. This form of rheostat is called the water-cooled rheostat, or immersed rheostat. A rheostat of this type has carried 800 amperes at 230 volts. Most of the coils were made of No. 14 galvanized-iron wire.

In the water rheostat, the carrying capacity varies greatly. A rheostat using a barrel holding 50 gallons of

water will dissipate about 50 kilowatts. The allowable current varies from .25 to 3 amperes per square inch of surface on the exposed face of one electrode. Enough water should be provided so that the water does not boil violently.

If the barrel or water-rheostat box is to be set on an iron frame, place the barrel or box in a tin drip pan and insulate the drip pan from the iron frame. It is very difficult to insulate a wet wooden box from the iron frame, unless a drip pan is used between the box and the insulation. When a rectangular box is used with the movable electrode moving in a vertical direction, it is well to use an iron plate the size of the bottom of the tank for the fixed plate, and to place the ring, which forms the movable electrode, at one end of the box. There will be a large body of water that is not active in carrying current, and this comparatively cold water will cool the portion of water which carries current from the top ring to the bottom plate. A circulation of water is set up which keeps the water at a fairly low temperature, unless the rheostat is heavily loaded.

GENERATING POWER FROM OIL FUEL

GEO. E. WALSH

LIQUID fuel has been used in the past year more than ever before in this country, and the discovery of the new oil wells in Texas and California combined with the anthracite coal strike, which put many manufacturing concerns to a great disadvantage, has suddenly given a new impetus to the use of oil as a fuel for power production. The price of oil has been brought down to the lowest on record, and at the present market rates it is considered as cheap as coal for fuel. In Texas and on the Pacific Coast it is far cheaper than anthracite or soft coal, and new factories and mills are being constructed there with boilers fitted solely for burning oil. The experiments so far obtained warrant the continuance, and even expansion, of the practice of building furnaces and boilers for liquid fuel.

The burning of oil under boilers is so different from that of coal that considerable experience must be obtained to make the fireman efficient in his work, for economy in burning oil is just as imperative as in burning coal. Oil is fed to the furnace in an entirely different manner, and the flame produced is more active and energetic than that produced by coal. The method of handling the liquid fuel is to pump it from some storage tank nearby, and then feed it through pipes to the furnace tank. In this latter tank the oil is slightly heated, but not sufficiently to cause any danger of ignition and explosion. Small steam pumps usually carry the oil from this furnace supply tank to the burner itself, forcing it along under a pressure varying from a few pounds up to twenty. As it passes through these pipes to the burner it is heated to a temperature from 150 to 190 degrees Fahrenheit so that when it reaches the burners it is quickly ignited.

The nature of the burners found to give the most satisfactory results is simple. Two disks perforated with numerous holes are arranged over each other in such a way that anything forced out of them will cross. The oil is forced through one of these disks in the form of powerful jets, and

from the lower circular disks comes either hot air or steam to break the oil up into a spray. The pressure of the steam is regulated to suit the needs of the boiler, but it is always strong enough to force the oil into a spray, permitting it to ignite instantly upon entering the furnace. The relative power exerted by the steam and oil jets determines to a considerable extent the efficiency of the fuel in burning. Under proper manipulation the flame from the burning oil spray fills the entire furnace box, and this gives active heat to all parts without raising the temperature of one higher than that of another. The main object of this spray burner is to distribute the heat so evenly that every part of the furnace box will be equally hot, and at the same time to produce perfect combustion.

In burning liquid fuel total and perfect combustion is practically obtained. There are no colored gases leaving the smokestack, and the burning is odorless so far as it is possible to detect any unpleasant gases from the stack. This of itself is considered an important improvement over coal burning. The economy in oil burning comes from the general nature of construction of the boiler and furnace and to the manipulation of the fire. Where properly constructed and handled it has been found that there is fully twenty per cent. less deterioration in the steam plant because of less wear on the furnace in throwing fuel in and in opening and shutting the fire-doors. There is no accumulation of ashes to clog the machinery and to make frequent cleaning necessary; neither are there any chemical combinations of gases and fumes to corrode the fire sheets inside of the furnace. In the same category mention should be made of the fact that the repairs of furnaces, grate bars, flue lining and so on are far less where oil is used than coal because of practically the same reasons as given above to account for the reduction in the deterioration of the plant. In order to square the account properly for a fair comparison mention should be made of the saving in the small items such as coal scoops, steel brooms, wood for starting fires and many other sundries which in large coal-burning plants amount to a considerable sum in the aggregate.

In obtaining economy in burning liquid fuel the temperature of the smokestack must be carefully measured and watched, for only by graduating this to the needs of the plant can one save waste of heat. By means of a high-temperature thermometer located in the smokestack it is possible to regulate the heat so that waste is reduced to its lowest minimum. The evaporative efficiency of the burners should be kept as high as possible, and this is made possible only by regulating the burners under each boiler by means of the ash-pit door. By closing or opening this an inch the heat of the smokestack will be raised or lowered 150 to 200 degrees in a short time.

In a great many plants oil is burned in preference to coal because of its convenience and similar advantages aside from the actual cost. It has been used in some factories within city limits even when the price of oil made the fuel more expensive to use than coal. Liquid fuel in the modern plants increases the capacity of the boilers and the capacity of the chimney, but to accomplish this the firemen and engineers must be thoroughly competent men. In fact, experience has shown that it pays to offer higher wages to a thoroughly skilled and capable fireman and engineer for the oil-burning plant than to depend upon

men of limited experience. There is, consequently, growing up a demand for better skilled men in the fireroom of the oil-burning plants than has been the case in the past. A good fireman and engineer working intelligently together can save far more than their wages amount to. The work to be done by them is not hard, but it requires intelligence and skill. There is little of the hard, dirty work which the fireman meets in a coal-burning plant.

The grate bars of an oil-burning furnace are left in about the same position as when coal is used, but they are covered with a layer of specially prepared, fine brick, and these bricks practically enclose the entire grate except a small space in front through which air for ventilation is allowed to enter. The furnace doors and the bridge are not changed from those used in a coal-burning furnace. Consequently, it is not so difficult to convert a furnace built for burning coal into one suitable for burning oil. A competent mechanic and engineer should be able to do this within a few days. There are a few extra equipments required, but after these are once installed the convertability of the furnace is assured. Within an hour arrangements can be made then to burn coal, or if desired, oil. This very fact of being able to construct the furnace in such a way that it can use either coal or oil on short notice has made this type of grate and furnace popular. In the event of a prolonged coal strike manufacturers could easily turn to oil to prevent any interruption of business.

Plants with this double sort of burning furnace will probably meet with increasing favor, both for generating steam power and for producing electricity. Sometimes it is desirable to burn oil only a part of the time, and coal for the other part, and the furnace equipped for the double purpose is of important value. With a storage tank for oil it is possible to be perpared at any moment to burn liquid instead of solid fuel.

Unless the oil flows in a steady pressure to the burners the fire is always in danger of going out, thus causing a great deal of labor and trouble. This often happened in the early experiments with fuel oil, for it was found that with a low pressure of oil and a high pressure of steam at the burner the flames were easily blown out by the latter. On the other hand, if the oil pressure at the burners is larger than necessary, or if the steam jets should subside, there would be a waste of oil. Unless the oil is properly atomized or sprayed a good deal of it fails to burn but drips down into the lower part of the grate surface. This waste oil may in time fill the ash-pit and explode, and it also tends to cause smoking, which fills the tubes with a soot that is difficult to remove. Consequently, a steady, uniform pressure of oil and steam must be had at the burners. In the modern burners this pressure is obtained by the duplex steam pumps which always keep it steady and uniform. In the event of some oil escaping, and not burning when sprayed by the steam, there is provided in most plants a small safety valve which carries the dripping oil back to the storage tanks, and thus prevents any danger of an accumulation and subsequent explosion.

Nearly all of the modern boilers for burning oil fuel are provided with peep holes through which the fireman can watch his fire to see that all is well with it. There have been a number of explosions in the past through the carelessness of firemen who allowed

the fires to go out while the spraying oil continued to pour into the furnace. The gas from the oil thus heated would in time combine with the air and explode.

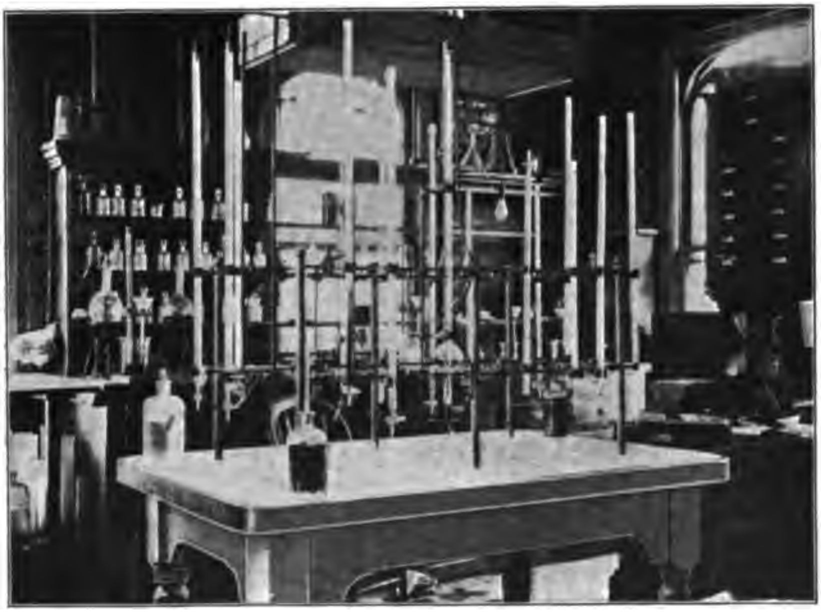
In selecting burners for a factory or mill, the chief thing to be sure of is that the machinery is sure to have the oil thoroughly atomized. Failure to do this properly means a constantly added expense. There will be a steady waste of oil which in the course of a year will amount to considerable. To test the efficiency of a modern oil burner one should turn on the steam and a small supply of oil. Then throw in a piece of oily waste when in full blaze. The fire should instantly start if the oil is properly atomized. Then manipulate the steam and oil supply by turning them partly off and on at full pressure to see how well they work together. If they cannot readily be operated so that the oil will burn steadily and actively without any smoke there is some trouble with the burner. If the steam and oil jets do not meet and spray satisfactorily there will be smoke in the stack and soot in the tubes. To avoid equipping a plant with any such deficient apparatus a series of thorough tests should be made beforehand, and if after the installation the apparatus shows any signs of such incomplete combustion the work should not be accepted as satisfactory. By simply increasing the supply of oil and steam in their proper proportion any degree of temperature should be obtained, and the boiler be forced to suit the demands of the work.

Another reason why the oil burners should be satisfactory in every particular, when equipped with the latest safety appliances, is that insurance companies refuse to place a risk on the factory or mill at any reasonable rates unless the burners prove efficient. Moreover, the question of the storage tanks for the oil must be carefully considered in building the plant. The insurance companies are very insistent upon having the large storage tanks a hundred feet from the main building if built above ground, and ten feet away if buried four feet under ground. The tanks must also comply with certain rules regarding manholes and vent pipes.

Efficiency in emergencies is one of the advantages of oil fuel which appeals with special force to those plants which require power on short notice, and which by the nature of the work makes it necessary for economical reasons to let the fire go out often. For this reason the passenger locomotives in California and Texas are run almost entirely by steam generated by oil fuel. Cleanliness and abatement of the smoke and gas nuisance are two other important considerations which influence many manufacturers today to install their plants with oil-burning furnaces and boilers. Economy of handling and concentration of material in small space tend to popularize oil as a fuel in the limits of cities where space for storage purposes is valuable and difficult to get. In view of all these considerations, and the present low price of oil and the high price of coal, the use of oil as a fuel for both steam and electric plants is increasing rapidly in popularity, while inventors are steadily applying themselves to the solution of problems which will make the present methods still more efficient.

TABLE FOR THE SUPPORT OF BURETTES

THIS table, designed by G. W. Englehart of the Buffalo Chemical Co., is solidly built of well-seasoned maple and has the following dimensions: Height from floor to surface of table, 31⅝ inches; length, 54⅝ inches; width, 36½ inches. It is surrounded by a flange of maple 2¼ inches wide and ⅞ inch thick, making the bed of the table ¾ inch deep. In this bed, white glazed tile 6 in. × 6 in. × ½ in. are laid in Portland cement and even with the edge of the flange piece, thus allowing ¼ inch for the cement.



There are 9 pieces of tile in length, allowing ⅝ inch for joints, and 6 in width, allowing ½ inch for joints.

The burette support is made of wrought-iron pipe. There are 6 upright pieces of ½-inch pipe with a flange attached to one end which is screwed to the bed of the table. These 6 vertical pipes pass through holes drilled in the tile and form a rectangle 38½ inches by 19 inches inside measurements, and are connected by a horizontal ⅛-inch pipe at a point 9¼ inches from the surface of the tiling. Ten inches above this horizontal pipe is another ⅛-inch pipe parallel to the first and completing the support. In the vertical pipes, holes were drilled admitting the horizontal pipes, which were soldered into place. To these horizontal pipes are attached the burette clamps.

This arrangement presents a neat and compact piece of apparatus (in this case, 24 burettes can be easily handled), all parts being perfectly rigid, and the clamps when once adjusted, always keep the burette perpendicular and the float (if used) in the right position.

Directly over this table is suspended a shelf carrying a lead pan, the bottom of which is covered with sand. This shelf serves to support the bottles containing the solutions which are siphoned to the burettes below.

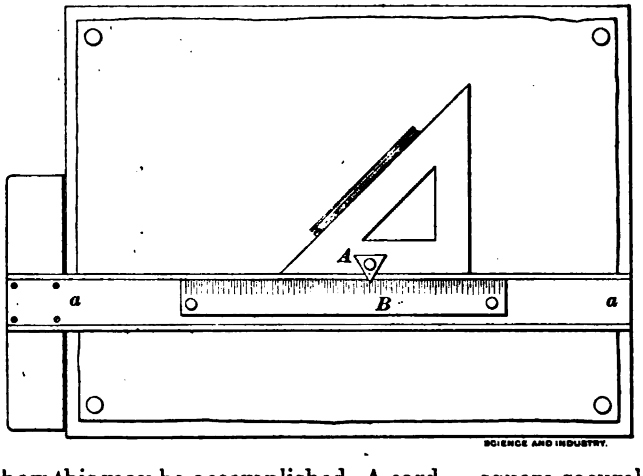
USEFUL IDEAS

Contributions to this column are solicited. Persons having "New Ideas" or schemes which they think are of general interest are invited to send them in together with sketches, where necessary, to illustrate. If acceptable, they will be paid for at our regular rates, if not, they will be returned to the sender. Address all communications to Editor SCIENCE AND INDUSTRY, *Scranton, Pa.*

A SIMPLE SECTION LINER

B. R. Winslow

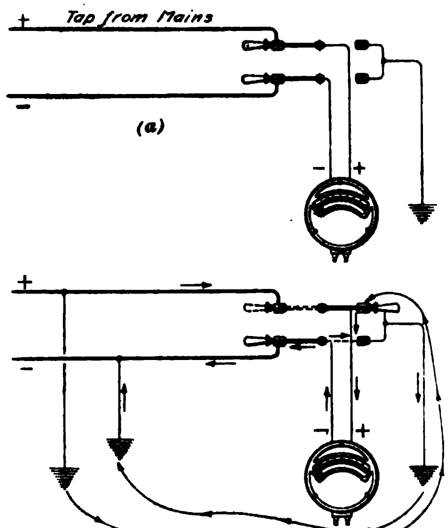
A simple, yet very accurate section liner, that will give complete satisfaction in every respect, can be constructed by any draftsman or student in a few moments, from his T square, 45° × 45° triangle, three thumbtacks, and a cardboard scale. The accompanying figure illustrates clearly how this may be accomplished. A cardboard scale *B* is fastened to the blade of the T square by means of two thumbtacks at each end, while a third tack securely fastens a wedge-shaped piece of cardboard *A* to the base of the 45° × 45° triangle. By sliding the triangle along the edge of the T square, stopping when the point of the cardboard indicator coincides with one of the division lines of the scale, and drawing a line along the hypotenuse of the triangle, at each stop, uniformly spaced section lines at an angle of 45° may be made. For all practical purposes a scale divided in 20 parts to the inch may be used. These scales may be purchased from any dealer in drawing material for 20 cents. They are generally 18″ long, but may be cut to any length to suit the convenience of the draftsman. It is best to prolong every other division line of the scale, and thus secure a scale divided 10 and 20 parts to the inch, the long lines indicating 10th inches and the shorter lines 20th inches. The thumbtacks used to pin the scale to the blade of the T square and the indicator to the triangle should be the smallest obtainable, and as an extra precaution against splitting and the points going entirely through the wood, the points should be filed down until they are about $\frac{1}{32}$″ long. The cardboard indicator can be made from a piece cut from the end of the scale. Two long-point thumbtacks at *a* and *a* will hold the T square securely in place and permit of the free use of the left hand. Section lines may be drawn perpendicular by changing the indicator point or at an angle of 30° or 60° by using the 30° × 60° triangle. If the indicator point is pinned to the hypotenuse of the 45° × 45° triangle, section lines at an angle of 45° can be drawn in two directions without changing the indicator. When not in use the indicator point may be turned around out of the way and the triangle and T square used for ordinary work.

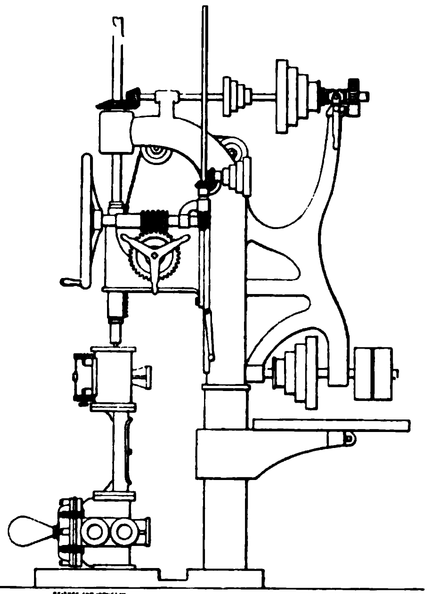


GROUND DETECTORS

In reading the article on "Ground Detectors," in the July issue, I thought of a rather simple way of getting the ground reading. The six-point switch is quite expensive, and comparatively few engineers are familiar with its use. The accompanying illustration shows the meter connections for a two-wire direct-current circuit requiring two single-pole double-throw baby-knife switches.

At *a* both single-pole switches are thrown over to the mains, thus indicating the regular voltage. By throwing the switch connected to the positive side over to the ground wire, as indicated at *b*, the leakage on the negative side is shown. By throwing the + switch back to the main and the — switch over to the ground wire the leakage on the + side is shown. The two-lamp method of testing for a ground does not seem entirely satisfactory, since on a 110-volt circuit it requires nearly 50 volts to start the lamps at all. A drop of 50 volts on a 15,000-volt Weston meter at 110 volts terminal pressure means a very low resistance ground, and the ground will get altogether too far along before the lamps will show it.





REPAIRING A STEAM PUMP

In many steam plants old steam pumps are found which have been discarded because they are worn out. The accompanying illustration shows how an enterprising engineer and machinist bored out the steam cylinder of one of these, and made it as good as new.

He did not have a lathe large enough to admit it, so he turned it on one end, and put it under the drill press which was fitted with a power feed attachment.

The supplemental steam cylinder, also the water cylinder, was rebored in the same way. If this plan is tried it is well to be sure that the feed will carry the cutters down far enough to go entirely through the cylinder.

EDITORIAL COMMENT

We frequently receive letters asking for information in regard to the profession of steam engineering. Among the questions more commonly asked are the following: What knowledge is necessary for a man to become a professional engineer? What are the duties generally performed by a professional engineer? What is the difference between a professional engineer and an operating engineer? By operating engineer we mean the man who actually runs the engine and cares for its ordinary wants. He is commonly called the engineer, engine runner, or engine tender. To be a competent operating engineer requires a sufficient knowledge, gained from actual experience with steam machinery, to perform the ordinary duties necessary for the efficient and economic operation of a steam plant. From the character of the forces employed it is necessary that their control should be in the hands of a man who is sober and reliable, who knows enough concerning the machinery under his charge to keep it at all times within established limits of safety, and whose knowledge and judgment are such as to insure the safety of the plant even under unforeseen or accidental conditions. Such knowledge, experience, and judgment can only be acquired by intimate association with machinery, together with a reasonable amount of reading and study.

To be a competent professional engineer requires all the qualifications of the operating engineer and a great deal more besides. It requires knowledge of all the principles involved in the conversion of the latent energy of fuel into the power required in the mechanical arts. The professional engineer must not only know how to fire a boiler, but he must be familiar with the principles which govern the combustion of the fuel in the furnace in order to know whether or not all of the heat which the fuel is capable of producing is generated and applied in the best manner to further the economic operation of the plant. He must be able not only to operate every piece of machinery in the plant to the best interest of the purpose for which it is designed, but he must be able to determine its efficiency, and the efficiency of the plant as a whole. In case any machine is found wanting in proper efficiency he must be able to locate the defect and to design and execute needed improvements, and by ingeniously adjusting means to conditions to obtain the greatest results in product for the money expended.

If the operating engineer keeps the safety valve free to operate at the desired pressure, sees that the boiler is not injured by lack of water or excessive scalding, that the engine cylinder is kept free from water, its governor free to control its speed, and the integrity and adjustments of its various parts preserved, his duty is fulfilled. To the engineer, however, belongs the duty of ascertaining if the boiler is structually adapted to sustain the pressure which it is required to carry, whether the safety valve and other accessories are so proportioned as to perform their functions under any conditions to which the boiler may be subjected, and whether the engine and machinery of transmission are equal in their design and execution to the demands which may be put upon them. He must be able to demonstrate in advance the advisability or futility of propositions, the practical or experimental carrying out of which would involve the expenditure of large sums of money, and to design, select, and superintend the building of a plant

which shall be best adapted to the accomplishment of a given object under the conditions of its proposed environment.

Between the professional engineer and the operating engineer there is in practice no sharp line of distinction. The term engineer is applied to the laborer who works the lever of a hoisting engine, without the least idea of what makes it go, as well as to the man who is in responsible charge of thousands of horsepower of steam machinery and who brings to bear upon its design, operation, and management a thorough education in the physical and mathematical sciences.

The cost of power is one of the most important factors in the cost of manufactured products, exceeding in some instances the cost of the material itself, and the subject of economic power is always an interesting one to both the owner and employe, and one to which we have always given a large amount of attention. Most employers nowadays realize the importance of having an educated engineer in charge of their power plants. But it is probable that even in what we are pleased to call this advanced stage not one plant in one hundred is run at its highest attainable efficiency, and when managers realize that is is better policy to pay $2,000 or $3,000 a year to a competent engineer who can save as much in fuel and repairs, a decided benefit will accrue all around.

A case came to our notice a while ago where a superintendent of a large blast furnace in the middle west employed an engineer at a salary of $200 per month. After the man had worked for about two months he reported to the superintendent that he had received an offer from an eastern concern of a position at $250 per month. The superintendent, knowing that he had a valuable man, increased his salary $50 per month without a moments hesitation, and the machinery of the blast furnace is running more efficiently than it ever did before.

Our advice to the operating engineer who wishes to advance is to study his machinery, study his books, and look out for opportunties.

The economical compression of steam in the engine cylinder is one of the most important as well as one of the most interesting questions with which the engineer has to deal. The large number of factors entering into the consideration of the question render it comparatively difficult of solution, that of cylinder condensation being probably the most important. It is a fact well known to most engineers that when a quantity of gas is admitted to the cylinder at a certain initial pressure and then caused to expand isothermally down to a certain final pressure at which it is discharged from the cylinder, the effective work done by the gas depends on the *ratio* of the initial and the final pressures only, and is independent of the absolute values of these pressures. It has also been determined that a given quantity of gas put through a cylinder will do the greatest amount of effective work upon the piston when the point of cut-off and the point of exhaust closure are so adjusted relatively to each other that the ratio of compression will equal the ratio of expansion. From which it follows that a given amount of work will be done by the least amount of gas if the ratio of compression of the gas equals the ratio of expansion. These statements are true for the isothermal conditions of a periect gas and can be applied to the action of steam in an engine cylinder with so little error as not to seriously affect practical calcula-

tions. So we can now conclude that the maximum economy in steam consumption is attained when the point of cut-off and the point of exhaust closure are so adjusted, relatively to each other, that the ratio of expansion is equal to the ratio of compression. Thus, if we suppose that the initial absolute pressure in a non-condensing cylinder is 96 lb., the back-pressure 16 lb., and the cut-off is such as to give a terminal pressure of 24 lb., then the ratio of expansion will be $\frac{96}{24} = 4$. Now in order that the most economical conditions may prevail the ratio of compression should also be 4, thus giving $16 \times 4 = 64$ lb. as the point to which the compression pressure should rise. If the terminal pressure were 30 lb., the ratio of expansion would be $\frac{96}{30} = 3.2$; and the compression should then be carried to $16 \times 3.2 = 51.2$ lb.

A fault was discovered recently in a submarine cable. The cable ship which was sent to repair it found that the cable, which rested on the sea bottom at a depth of about 300 fathoms, had been nearly bitten through, the broken tooth of a huge fish being found embedded in the cable.

The first railway systems of the world were inaugurated in the following years, says Mechanical Engineer: England, Sept. 27, 1825; Austria, Sept. 30, 1828; France, Oct. 2, 1828; America, Dec. 28, 1829; Belgium, May 3, 1835; Germany, Dec. 7, 1835; Russia, April 4, 1838; Italy, Sept. 4, 1839.

BUSINESS NOTES

George William Hoffman, manufacturer of U. S. Metal Polish, reports that business is steadily increasing and that he is receiving orders from all over the world.

The structural steel work of the new Pennsylvania Building, 15th and Chestnut Streets, Philadelphia, has been painted with Dixon's Silica-Graphite Paint.

The Bangs Oil Cup Co., 116 Fowler Street, Milwaukee, Wis., have succeeded to the business of The Bangs Co. and will market a complete line of automatic oil cups.

The DeFrees Thermotor Co. have changed the name of the company and will hereafter be known as the Capital Thermotor Co., of Indianapolis, Ind., with Louis Ohnhaus, manager, and Henry Pokorney, formerly with the E. R. Thomas Motor Co. and Farar Trefts, Buffalo, N. Y., as superintendent of the works. The new organization will manufacture both two- and four-cycle engines from 1 to 100 horsepower. They are located at the corner of Hovey Street and Belt Railroad, Indianapolis, Ind.

The following recent incident illustrates the efficiency of the United States Mail Service: At Rock Island, Ill., there was deposited, in a United States mail box, a letter upon the envelope of which was pasted a picture evidently representing some railway passenger agent. This was all there was upon the envelope. That the picture was some railway passenger agent the post office authorities determined from the uniform, and, under a microscopic inspection, discovered that the cap bore the inscription—Chicago & Alton R'y Passenger Agent. Upon reference to a Chicago & Alton R'y folder (in which appears the pictures of depot passenger agents at terminals to enable passengers to readily recognize passenger agents who meet incoming trains and assist passengers in boarding outgoing trains), the post office authorities discovered a similar likeness, and found that the individual to whom the letter was addressed was Mr. Price M. Taylor, Depot Passenger Agent, Chicago & Alton R'y, St. Louis, Mo. The letter was then forwarded, reaching Mr. Taylor three days after it was mailed in Rock Island.

Sargent & Co, New Haven, Conn., have gotten out a little circular descriptive of some of the tools manufactured by them.

The C. W. Hunt Co. have issued an attractive circular illustrative of their industrial railway systems.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

MECHANICAL

(262) To get the best results from exhaust steam heating, which is the better method, to have the steam and the water enter the heater at the same end and travel in the same direction, or to have the steam enter at one end and the water at the other, and pass in opposite directions?

J. C., Helena, Mont.

ANS.—You will get the best results by having the steam enter at one end and the water the other, and have them travel in opposite directions.

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(263) Please state through the columns of your paper the name of some good book on steam engineering.

C. L. M., Imporia, Kan.

ANS.—There is no one book which covers the whole subject of steam engineering. If you wish to educate yourself along this line, we should recommend that you take a Course in the International Correspondence Schools. You can obtain a better knowledge of the subject in this way than in any other that we know of.

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(264) Can the noise caused by the exhaust from a very large steam drop hammer be prevented or in any way lessened? Would the use of a condenser help any and what would be the best type for the purpose? Any suggestions will be appreciated.

W. D. G., Staten Island, N. Y.

ANS.—It is our opinion that an exhaust head would answer your purpose nearly as well as a condenser and would entail far less expense in first cost and subsequent operation. It would be necessary to use a very large size of head, because the exhaust from a steam hammer is very heavy. Steam is carried full stroke in the cylinder of a hammer and consequently it is released at a pressure but little below boiler pressure. The use of a condenser would, undoubtedly, completely stop all sound caused by the exhaust, but as a steam hammer is used intermittently the condensing machinery would be running a large part of the time during which its services would not be required, thus causing a continuous expenditure without producing useful results. The type of condenser that is best suited for any given class of work depends so much on local conditions that it is impossible to give a general rule for its selection. Other conditions being equal, however, it is safe to state that condensers that have no moving parts and do not use steam are cheapest in first cost and in expense of operation. The induction condenser and the siphon condenser may be mentioned as illustrating this type.

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(265) (*a*) Please explain by example how large a hole can be safely cut in a steam boiler without having to put on a ring. Please give constant for steel and iron. (*b*) Can the guides on an engine be used for leveling the engine on the foundation? (*c*) Have you ever published any instructions for setting the valve on a Corliss engine?

W. F., Hattiesburg, Miss.

ANS.—(*a*) It is impossible to give any formula or constant for such a thing as this. It depends largely on the thickness of the plates and the pressure inside of the boiler. As a general thing it is better to reinforce with rings all the holes more than 2 inches in diameter. Experience and good judgment are the best guides in a matter of this kind. (*b*) Yes. (*c*) See the Home Study Magazine for December, 1898.

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(266) I am running a 15-ton, direct-expansion refrigerating plant, having one chill room, 38′ × 25′ × 18′, and piped with 1,800 feet of 2-inch pipe. Can you tell me why at a temperature of 38 degrees, I can only carry 10 pounds back pressure without going over my pumps?

G. P., Ludlow, Ky.

ANS.—If you are doing satisfactory work with only 10 pounds on your coils, we should say that you are getting very good results and we would not advise you to

attempt to carry a higher pressure. The lower you can carry the pressure and do the work, the higher the efficiency of the plant. If you are not doing satisfactory work, we should say that the trouble must be due to either water or air having become mixed with the ammonia. To test the ammonia liquid for water, draw off some of it into a large-mouthed bottle, fitted with a rubber cork, having a small hole about $\frac{1}{8}$-inch in diameter through it. Allow the ammonia to evaporate, and if there is the slightest trace of water left in the bottle, the entire charge should be withdrawn and sent to the manufacturers for the removal of the water. Before putting in a new charge of ammonia, air should be blown through the coils in order to dry out the pipes thoroughly. Next close the expansion valve and run the machine until there is a vacuum of about 28 inches in the coils, when a new charge may be introduced. To test the ammonia for air, it is necessary to withdraw the entire charge into a receiver and allow it to stand about 10 hours undisturbed. Air being lighter than liquid ammonia, it will rise to the uppermost part of the receiver and then can be drawn off through the purging valve with which most receivers are fitted. If you attach a small rubber hose to the purging valve and lead the discharge under water, the character of the bubbles will indicate when all the air is out and ammonia is escaping. The unpleasant smell is also avoided by this means.

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(267) What causes the nosing or lateral play found most generally in the eight-wheel locomotive?

J. R. B., Somerset, Ky.

Ans.—Nosing in an engine is not due to the lateral play or lost motion between the engine-truck box and the wheel hub, neither is it due to improper counterbalancing. The side-to-side movement of locomotives mentioned is most noticeable in the eight-wheeled locomotive and is due to the cylinders being placed outside of the rails, thus causing the reaction of the steam, acting between the ends of the cylinders and the pistons, to produce a tendency to swing the boiler from side to side out of alinement with its proper position on the driving wheels. The tendency to produce nosing is caused as follows: Suppose the engine to be using steam, then, as steam is admitted to, say, the front end of the right cylinder, it forces the piston away from the front cylinder head; the force exerted on the piston is transmitted to the main driving wheel through the piston rod, and main rod, hence, the action of the steam in the cylinder really produces a tendency to force the right front cylinder head away from the right main driving wheel, which tends to throw the front end of the boiler sideways. Now, as steam is admitted to the front end of the right cylinder, it is being expanded in the back end of the left cylinder, so that the tendency of the steam in the left cylinder at this time is to force the piston (and, therefore, the main driving wheel) and the left front cylinder head nearer together, thus tending to pull the front end of the boiler sidewise. Therefore, as the right piston begins its back stroke the action of the steam in both cylinders produces a tendency to force the head-end of the boiler to the left of its proper position with respect to the driving wheels. As the piston on the right side takes its forward stroke, the action is reversed and the tendency produced by the steam in the two cylinders is to force the front end of the boiler to the right of its proper position. Thus, there is a tendency to move the front end of the boiler alternately to the left and to the right, and when the movement occurs the engine is said to nose. Nosing is especially noticeable in eight-wheeled locomotives having a swinging main truck. It is least noticeable in eight-wheeled and ten-wheeled engines that have rigid trucks. Nosing is also noticeable in switch engines and in engines having pony trucks. Although the tendency to nose is present at all times, yet nosing does not occur on curves, for the reason that the engine is crowded against the outer rail with a force that is greater than that producing the nosing. However, as soon as the engine rights itself on a piece of straight track, nosing begins and, on account of the accumulative effect of the force producing the nosing, the side swing gradually becomes greater until it attains a certain amount for the speed, when it remains about constant. Besides nosing, there is an up-and-down movement of the front end of the boiler. This is produced by the upward thrust of the cross-head against the guides, due to the angularity of the main rod.

ELECTRICAL

(268) Please state the reason for a coil on an armature burning out, when the two commutator segments to which a coil is connected are short-circuited.

F. E. P., Chicago, Ill.

Ans.—The coil, the two segments, and the short circuit between the segments form a complete circuit of low resistance. The sides of the coil, which are on the armature, cut across the magnetic lines of the pole pieces and have set up in them E. M. F.'s. As the closed circuit of this coil has a very low resistance, it is necessary that only a low E. M. F. be set up in the active portion of the coil, in order to force a very large current through the coil and the two short-

circuited commutator bars. The coil is burned out because of the heating action of their large current.

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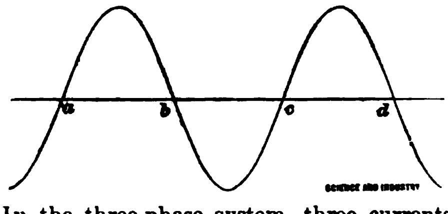
(269) (*a*) What is a synchronous machine and what is it used for? (*b*) What is the difference between a transformer and a converter? (*c*) What is meant by single-phase, two-phase, and three-phase currents, and why cannot a single-phase machine be run in parallel with a two-phase machine? (*d*) What is meant by a machine running so many cycles, such as 25 cycles, 60 cycles, and so on? (*e*) A certain Westinghouse alternator has an armature wound for both direct and alternating current. It also has an exciter. How much of the current does the exciter furnish to the fields, and which governs the potential, the exciter or the winding on the armature?

C. H. B., New Richmond, Ohio.

Ans.—(*a*) A synchronous machine is a machine that runs in synchronism with or at the same frequency as the machine that supplies it with current. The most common examples of synchronous machines are rotary converters and synchronous motors. If a synchronous motor or rotary converter has the same number of poles as the alternator, it will run at exactly the same speed as the alternator supplying it with current. If it has a different number of poles it will run at a speed such that its frequency is the same as that of the alternator. Synchronous motors are used for supplying power. Rotary converters are used for changing alternating current to direct current or vice versa. (*b*) There is no difference. Both terms are used to express the same thing, so the use of the term converter in this connection is gradually going out. (*c*) It is not strictly correct to speak of a two-phase or three-phase current. In a two-phase system two single currents, or single-phase currents, as a simple alternating current is generally called, are used, and these two currents differ in phase by one-quarter of a complete cycle.



In the three-phase system, three currents differing in phase by one-third of a complete cycle are used. It would be possible to run a single-phase in parallel with a two-phase machine feeding current into one side of the two-phase system, but it would not be done in practice because it would cause the two-phase system to become unbalanced. (*d*) It means that the current passes through say, 25 complete sets of values per second. An alternating current is continually reversing its direction of flow, as indicated by the accompanying curve. It flows say, in the positive direction during the interval of time represented by *a b*, and in the negative direction during the interval represented by *b c*. The complete set of values from *a* to *c*, consisting of positive and negative half waves, is called a cycle, and if the current passes through 25 of these per second, the frequency is spoken of as 25 cycles. (*e*) The exciter does not furnish any of the current delivered by the large machine. It simply sends current around the fields of the alternator. The exciter governs the potential to a certain extent, because any increase in the voltage of the exciter increases the field current of the alternator, and, therefore, increases the voltage of the alternator. The voltage of the alternator also depends upon the winding on the alternator armature, but this winding cannot be altered in any way, so that voltage adjustments must be made by varying the field excitation.

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(270) The line wires connected to a 60 K. W. Westinghouse alternator were struck by lightning, which caused a heavy ground on the wires and formed a partial short circuit, so that for a short time a large current was flowing in the alternator armature. The lights on the line went down to a dull red. The alternator was shut down and examined. It was found that some of the wires connected to the rectifying commutator were unsoldered. The wires were soldered in place, the machine started up, and the lights built up to their normal voltage. It was noticed that taking up the four brushes on the rectifying commutator did not affect the E. M. F. of the machine. Why can these brushes be lifted without any affect on the machine E. M. F.?

E. B. J., Nevada, Iowa.

Ans.—When the lightning struck both line wires and made a heavy ground, the alternator became partially short-circuited through the line wires and ground on each line wire. This caused a large current to flow through the armature of the machine. A large portion of the generated E. M. F. is used up in forcing current against the self-induction of the armature coils; thus the lamps burned red. The rectifying commutator is supplied with current from the secondary of a small transformer mounted on the armature. The primary of this transformer consists of a few turns of wire through which the main armature current passes. If the current in the primary turn of this transformer become excessive, the E. M. F. and current in the secondary coil of the transformer becomes excessive. This large current in the secondary coils and commutator may have been sufficiently large

to cause the commutator leads to become unsoldered. The probability is that the large current may have caused an open circuit in some part of the secondary circuit of the small transformer. In that case the commutator would not be furnished with current, and therefore raising the brushes on this commutator would not affect the E. M. F. of the machine, as the commutator has no current flowing through it. It may have been that instead of being burned out as described above, the lightning entered the armature, jumped to the secondary coils of the transformer, to avoid the self-induction of the armature windings, and thus open circuited either the secondary of the transformer or some part of the compensating coils. When the machine is in good order current should be supplied to the compensating coils on the pole pieces, from the commutator, and it would probably greatly affect the E. M. F. of the alternator, if the brushes on the commutator were raised, when the alternator was carrying a considerable part of its regular load. In case the secondary circuit of the small transformer is open, as suggested, the field rheostat in the alternator separately excited field circuit, or the exciter shunt-field rheostat, would probably have to be adjusted so that for a given load on the alternator, more resistance would have to be cut out of the rheostat than when the alternator was running at the same load when it was in perfect condition. We would suggest that an examination be made of the small armature transformer, and the compensating coils, and that they be tested with a magneto for open circuits.

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(271) (*a*) Please explain the following formula for a simple wave:

$$y = a \sin(pt - nx).$$

(*b*) Why does a rainbow form a curve? (*c*) What in your opinion is the best theory for the Gulf Stream? (*d*) I have a small induction coil. When I connect the primary wires to a battery and touch my tongue to one of the secondary wires a slight shock is felt, although I touch no other wire but the one, and sit on a chair insulated by being placed on plates of glass. Only four or five "Sampson" cells are used. From the other secondary wire the shock felt is not nearly so great. Explain.

G. F. G., Halifax, N. S.

ANS.—(*a*) The simple wave is known as a sine wave, i. e., the ordinate of the wave at any point is proportional to the sine of a uniformly variable angle. For example, in the figure let the line oa, of constant length, represent the constant a in the formula, and let x represent an angle which changes uniformly as oa revolves in the direction of the arrow, then the line $ba = oa \sin x$. As oa revolves, the line ba increases from zero to a maximum $= oa$, then decreases to zero, increases to a maximum in the opposite direction, and finally comes back to zero again. If we lay off fd, which will represent to scale the time taken for a to move from g to a, and erect at d a perpendicular dc equal to ab, a point c is obtained on the wave. Other points can be found in a similar manner, thus giving the wave $fchklm$. You will find a fuller explanation of the sine curve in connection with the articles on "Alternating Currents," appearing in the magazine. (*b*) and (*c*) We have no theories in regard to rainbows or Gulf Streams. (*d*) It takes but an extremely small current or discharge to make itself felt on the tongue, and as you were dealing with a fairly high voltage it is quite possible that there was leakage enough to make itself felt. The amount of shock felt at either would depend on the point in the winding where the leakage occurred. It is quite possible that a small static discharge would produce the effect you mention.

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(272) (*a*) How can the candlepower of a lamp be calculated? (*b*) Would the candlepower of an acetylene gas burner be increased by using a reflector?

R. F., 2423 New Orleans, La.

ANS.—(*a*) The candlepower of a lamp is measured on a photometer, not calculated. A standard gas flame is arranged at one end of a bar and the lamp to be measured at the other end. A carriage bearing a screen and mirrors, for comparing the intensities of the light, is mounted on the bar and is movable. The screen and mirrors are moved to such a point that both sides of the screen are equally illuminated. The candlepower of the lamp being tested is found by multiplying the candlepower of the standard gas flame by the quotient obtained by dividing the square of the distance of the lamp from the screen, by the square of the distance of the standard from the screen. (*b*) The mean horizontal candlepower of the lamp itself would be the same, but there would be a much stronger light in one direction as the light rays are concentrated by the reflector.

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(273) Please give me a formula for determining the size in circular mils of the conductors for a direct-current, three-wire system.

J. R. S., Raton, N. Mex.

ANS.—One formula for this purpose is, $A = \frac{5.4\,NF}{E}$. A = the cross-sectional area of the outside wires in circular mils. N = the total number of 16-candlepower lamps. F = the single distance in feet between the dynamo or distributing board and the lamps. E = the total drop in both outside line wires. For example, if the pressure at the dynamo were 112 and that at the lamps 110,

the drop on each side of the system would be 2 volts and the value of E would be 4. The neutral wire is usually from one-half to the full cross-section of the outside wire. Practice differs in regard to the size of the neutral wire. The wiring problem can be solved by the use of a two-wire system formula. $A = \frac{21.6 \times D \times C}{e}$. D is the distance in feet one way from the station to the center where the power is delivered. C is the current in amperes that flows in the outside wires. The current in the outside conductors of a 110-220 volt, three-wire system is found by dividing the total number of lamps by 4. The drop e is the total drop in volts in both outside line wires. A = the cross-sectional area of the outside conductors.

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(274) (*a*) How is it that one side of an arc lamp will burn and the other will not, although the brush touches the rod? (*b*) How can I hang an arc lamp and know that I hang it on the right side, without starting the dynamo? (*c*) What is meant by forming the arc?

G. A. P., Republic, Mich.

Ans.—(*a*) In one style of arc lamp the washer carbon clutch on one side is narrower than the washer carbon clutch on the other side. When both carbons are down against the lower carbon and the lamp started current flows through both carbons. The narrower clutch grips its washer first and separates one set of carbons first. The current then flows through the other set of carbons and the arc between this set of carbon is formed by the still further lifting of the clutch, which makes the wider clutch grip its washer which separates the carbons of the last set. The separation of the first set is too great to admit of the formation of an arc between them, until the other set of carbons is so far consumed that they cannot be brought together for relighting, when the first set is lowered into contact, the arc formed, and this set put into active operation. (*b*) If the terminals of the lamps are marked + and —, and it is known which line wire is to be connected to the + terminal of the arc dynamo, and which line wire to the — terminal, the lamps can be placed correctly by connecting the + lamp terminal to the wire connected to the + terminal of the dynamo and the — lamp terminal to the wire connected to the — terminal of the dynamo. If the polarity of neither lamp nor wires is known, connect in the lamps, run the dynamo and then examine each lamp. Cut out each lamp by the cut-out switch on the top of the lamp. See which of the carbons is the hottest; the one that glows the longest is the positive. The positive should be the top carbon if the lamp is connected correctly. Make the test on each of the lamps. Note the positions of the lamps not connected properly, and after the current has been cut off the line reverse the terminals of the faulty lamp so that the positive carbons will be on top. (*c*) The arc is formed when the carbons are separated, the arc being drawn out between the ends of the top and bottom carbons.

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(275) Please state the size of wire and the number of turns of wire on the primary and the secondary coil of an induction coil for a motor bicycle. The coil is without the ordinary vibrator.

L. T., Greely, Colo.

Ans.—The following dimensions of coils are recommended by Stoddard. Length of coil, 8 inches; outside diameter, 3½ inches; diameter of core, 1 inch; primary coil consists of two layers of No. 14 or No. 16 B. & S. wire. The secondary coil is wound to a diameter of 3½ inches with No. 32 or No. 36 B. & S. wire. Use six cells of battery connected in series. For further particulars, see an article in the Horseless Age, beginning May 23, 1900, on the "Construction of a Jump Spark Coil," by E. J. Stoddard. Great care should be taken that the primary coil is thoroughly insulated from both the core and the secondary coil. It is well to wind in a piece of paper between every two or three layers in winding the secondary coil. When the coil is used in connection with a gas engine, the automatic interrupter in the primary circuit may be used or not used, if a portion of the gas-engine machinery completes the primary circuit periodically. In some cases the automatic interrupter at the end of the core of the coil is used, and other times it is not, and the variation in the magnetism of the coil core is caused by the making and breaking of the primary circuit through the contact, which is made and broken by means of the portion of the moving gas-engine machinery.

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(276) (*a*) In rewinding one of the field coils of a small direct-current fan motor, there was a considerable less number of turns of wire put on than the original coil contained. Why does the motor run faster than formerly? (*b*) If both coils had been rewound with a less number of turns of wire what would have been the result? (*c*) Why is it that the motor will not start up until the full speed contact is reached, on the starting switch? J. O., Passaic, N. J.

Ans.—(*a*) We presume that the motor is a series motor. By decreasing some of the turns of wire the field strength is weakened. In order that the armature may generate enough counter E. M. F. to hold back the current to the value necessary to drive the load on the motor, the armature must

revolve much faster, as the armature conductors are cutting across a field of much less density of magnetic lines than before. In order, then, to generate the proper counter E. M. F. the armature conductors must cut across the magnetic field at a higher rate of speed. (*b*) The speed of the motor would be still higher. (*c*) As the field strength has been decreased and the torque depends upon the strength of the magnetic field set up in the pole pieces and in the armature, the magnetic field set up by the current in the armature must be increased because of the decrease in the magnetic field in the pole pieces. As the number of armature conductors has not been changed, the current taken by the armature must be increased, so that the extra starting resistance must be cut out before the armature gets current enough to start.

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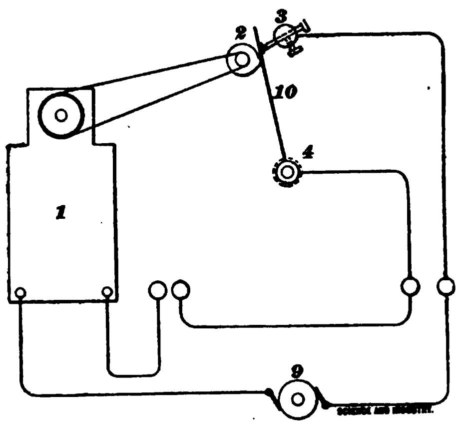
(277) I wish to make a transformer from your instructions in the July number, and as I have no alternating-current dynamo, I wish



to use the transformer with a shunt-wound, 55-volt, direct-current dynamo. The accompanying sketch will give an idea of the method I intend to use for making alternations in the current. Please advise if this will work all right. *2* is a small cam which, when revolved, makes contact with the spring *10*. This spring will then come in contact with *3* and make a circuit. As soon as spring *10* leaves *3* there will be a break in the circuit, thus giving rise to alternations. The small motor *1* is connected in series and is used to run the vibrator.

C. J. Twist, Norwich, Conn.

Ans.—This device would not work well with a transformer. You would simply get an interrupted direct current and not an alternating current; that is, the current would not flow first in one direction and then in the other as is the case with an alternating current. Assuming that this device could be made to operate without sparking, it might answer for an induction coil, but not for an ordinary transformer.

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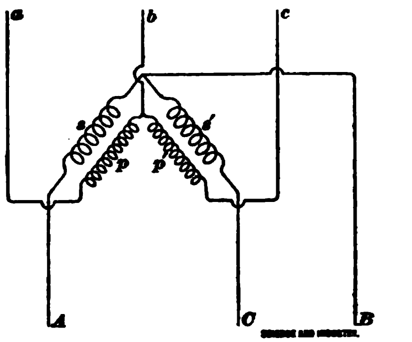
(278) (*a*) In the accompanying sketch is shown a diagram of the connections of two transformers connected to a three-phase system. The primary coils are connected to the wires of the high-tension line, as



shown. The secondary coils are connected to a three-phase secondary system. What is the theory of this connection? (*b*) Will transformers used in this way give as good service as three transformers connected in star or delta connection?

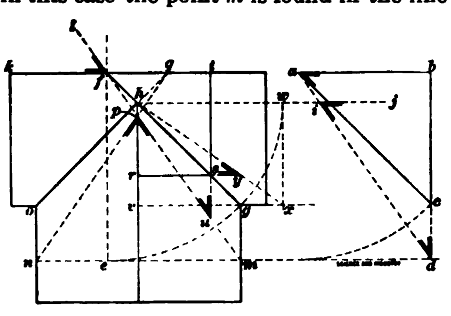
C. S. C., Bane, Vt.

Ans.—(*a*) See accompanying sketch. *p* represents the primary coil of one transformer having a secondary coil *s*. *p'* is the primary coil of the other transformer. The secondary coil of this transformer is represented by *s'*. The E. M. F. between *A* and *B* and between *B* and *C* depends upon the E. M. F. between the high-tension lines and the ratio of transformation of the transfomers. The E. M. F. between *A* and *C* is the geometrical sum of two E. M. F.'s out of phase with each other. The resulting E. M. F. between the outside ends of the two secondary coils depends on the E. M. F. of each coil and the phase angle between them. By varying the magnitude of the component E. M. F.'s and the angle between them, the resultant E. M. F. may have any desired value and any direction with reference to either component. Each of the secondaries contributes its part of the output in the resultant phase, and the secondary circuit behaves substantially as if it were derived from the ordinary mesh connection. (*b*) This system is sometimes used in connection with small motor work, thus saving the expense of one transformer. The objection is that if one transformer burns out the system is disabled. If three transformers were used and one burnt out, it might be possible to run, at least temporarily, with two transformers.

MISCELLANEOUS

(279) Will you inform me of a method by which I can determine the length of the cuts for the valley- and jack-rafters of two intersecting roofs? The roofs are each half pitch, but the width of the main building is 16 feet, while the width of the intersecting roof is 14 feet. H. B., Sundow, Minn.

ANS.—In the figure the outline of the roof and the members is shown in heavy lines, while the construction necessary to determine the lengths of these members and their cuts is designated by dotted lines. The valleys are $o\,h$ and $g\,h$, and $g\,h$ is extended to the ridge $a\,k$, where it cuts against it, while the valley $o\,h$ cuts against the valley $g\,h$. One set of jack-rafters is shown at $r\,s$ and $s\,t$. First, to determine the cuts and the length of the valley $g\,f$, draw the outline section or elevation of one-half of the roof, as shown at $a\,b\,c$; then from the point f draw the line $f\,e$ perpendicular to the ridge; with the dividers set at f, revolve $f\,g$ until the intersection e is obtained; then project e to the point d and draw in $a\,d$; the length of the valley will be equal to the length of the line $a\,d$; the plumb-cut at the upper end of the valley will equal the angle made by the intersection of any line perpendicular to $c\,b$ and the the line $a\,d$; for instance, the plumb-cut will be $j\,i\,d$; the foot-cut of the valley will be $c\,d\,i$. These cuts will likewise be the plumb-cut and foot-cut for the valley $o\,h$. In order to determine the cheek cut for $f\,g$ it is necessary to revolve $a\,c$ until it intersects a perpendicular line with the ridge through a, and project this intersection to the point m; in this case the point m is found in the line



$e\,d$, which happens on account of the roofs being a half pitch. When m has been thus determined, draw $f\,m$, and the angle $k\,f\,l$ will be the cheek cut of the valley $f\,m$. To determine the cheek cut of the valley $o\,h$, project m to n, and draw through n a line to the point q, which coincides with the intersection of $o\,h$ extended and the ridge. The cheek cut of the valley $o\,h$ will then equal $n\,p\,m$; the length of this valley is $i\,d$. Since both roofs have a one-half pitch, the plumb-cut for the jack rafters $r\,s$ and $s\,t$ is the same, and this cut is the angle $b\,a\,c$. If the roofs were not one-half pitch, the angle $b\,a\,c$ would, in any case, equal the plumb-cut for $s\,t$, but in order to determine the plumb-cut of $s\,r$ it would be necessary to lay out an end view of the gable similar to the end view of the roof represented by $b\,a\,c$. The foot-cuts for these jack-rafters are the same as the plumb-cuts. The cheek cut for the jack-rafter $s\,t$ is found by extending $s\,t$ until it intersects $m\,f$ at u; then the cheek equals $s\,n\,p$. The cheek cut for the jack-rafter $r\,s$ is equal to $h\,y\,s$, and is determined by revolving $h\,g$ around the point h until it intersects a line parallel with the ridge at w, the point w being projected to x, and $x\,h$ drawn. The length of these rafters is readily found from a normal section through the main roof, and through the intersecting roof. While this method may appear somewhat complicated, it is really simple, and though the method can be simplified for half-pitch roofs, it must be remembered that this method is applicable for roofs of any pitch.

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(280) In the answer to Ques. 323, b, for July 1900, the following formula is used:

$$\left(A-\frac{1{,}200\,B}{R}\right)\left(1+\frac{R}{1{,}200}\right)^n+\frac{1{,}200\,B}{R}=0.$$

How is this formula derived?

G. E. F., Pittsburg, Pa.

ANS.—The problem is to pay A dollars at R per cent. interest per annum in n monthly payments of B dollars each. The interest on \$1 for one month is $\frac{R}{1{,}200}$ dollars. The amount of \$1 for one month is $\left(1+\frac{R}{1{,}200}\right)$ dollars, and for A dollars for n months is $A\left(1+\frac{R}{1{,}200}\right)^n$ dollars. That is, the amount if paid in one payment at the end of n months is $A\left(1+\frac{R}{1{,}200}\right)^n$ dollars. But the first payment is made in one month or $n-1$ months before the expiration of the n months; hence,

amount of first payment is

$$B\left(1+\frac{R}{1{,}200}\right)^{n-1}.$$

Similarly,

amount of second payment is

$$B\left(1+\frac{R}{1{,}200}\right)^{n-2};$$

amount of third payment is

$$B\left(1+\frac{R}{1{,}200}\right)^{n-3};$$

* * * * * * * * * *

amount of next to the last payment is

$$B\left(1+\frac{R}{1{,}200}\right);$$

and the last payment is B.

Beginning with the last payment and adding gives the sum of the payments,

$$B + B\left(1+\frac{R}{1,200}\right) + B\left(1+\frac{R}{1,200}\right)^2 + \dots B\left(1+\frac{R}{1,200}\right)^{n-1}.$$

This is a geometrical progression and the sum is $\frac{1,200\,B}{R}\left(1+\frac{R}{1,200}\right)^n - \frac{1,200\,B}{R}$.

The amount of the payments at the end of n months is equal to the amount of the debt; hence,

$$A\left(1+\frac{R}{1,200}\right)^n = \frac{1,200\,B}{R}\left(1+\frac{R}{1,200}\right)^n - \frac{1,200\,B}{R}.$$

Transposing and combining,

$$\left(A-\frac{1,200\,B}{R}\right)\left(1+\frac{R}{1,200}\right)^n + \frac{1,200\,B}{R} = 0.$$

***

(281) An army in a battle lost $\frac{1}{4}$ of its number in killed and wounded and 4,000 prisoners. It was reinforced by 3,000 men, lost $\frac{1}{4}$ of its number in a retreat, and arrived in barracks with 1,800 men. What was the original number in the army?

H. C. S., Demerara, British Guiana.

Ans.—This problem is impossible. The 1,800 men were $\frac{3}{4}$ of the number that began the retreat. From this, 2,400 is the number of men in the army after it was reinforced by 3,000.

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(285) Solve the equations,

$$x^2 + y = 7. \qquad (1)$$
$$y^2 + x = 11. \qquad (2)$$

G. K., New Orleans, La.

Ans.—Solution 1.—Adding (1) and (2),

$$x^2 + x + y^2 + y = 18 \qquad (3)$$

Whence,

$$x^2 + x + \tfrac{1}{4} + y^2 + y + \tfrac{1}{4} = \tfrac{74}{4} = \tfrac{25}{4} + \tfrac{49}{4}. \qquad (4)$$

By inspection of (1) and (2), $y > x$. Then separating (4) into two equations,

$$x^2 + x + \tfrac{1}{4} = \tfrac{25}{4}. \qquad (5)$$
$$y^2 + y + \tfrac{1}{4} = \tfrac{49}{4}. \qquad (6)$$

From (5), $x = 2$ or -3.
From (6), $y = 3$ or -2.
By substituting -3 for x and -2 for y in (1) and (2), it is seen that these values are not roots of the equations. Hence, $x = 2$, $y = 3$. Ans.

Solution 2.—

From (1), $x^2 + y = 4 + 3. \qquad (3)$
From (2), $x + y^2 = 2 + 9. \qquad (4)$
From (3), $x^2 - 4 = 3 - y. \qquad (5)$
From (4),

$$x - 2 = 9 - y^2 = (3 - y)(3 + y). \qquad (6)$$

Whence, $\frac{x-2}{3+y} = 3 - y. \qquad (7)$

From (5) and (7) $x^2 - 4 - \frac{x-2}{3+y} = 0.$

Factoring, $(x-2)\left(x + 2 - \frac{1}{3+y}\right) = 0. \qquad (8)$

Setting first factor of (8) equal to zero,

$$x - 2 = 0,$$

whence, $\left.\begin{matrix} x = 2 \\ y = 3 \end{matrix}\right\}$. Ans.

***

(282) Explain the term centigrade as applied to heat, and the relation it bears to Fahrenheit. C. F. B., Buffalo, N. Y.

Ans.—The term centigrade is of French origin, and the centigrade thermometer is generally used in France. It is also largely used in this country for scientific work. In the centigrade thermometer the freezing point is taken at zero degrees, and the boiling point of water at mean atmospheric pressure at the sea level is taken at 100 degrees. One degree Fahrenheit is equivalent to $\frac{5}{9}$ of a degree centigrade, 1 degree centigrade is equivalent to $\frac{9}{5}$ of a degree Fahrenheit. To transform a reading on the centigrade thermometer to the Fahrenheit scale, multiply by $\frac{9}{5}$ and then add 32 to the result. To transform a reading on the Fahrenheit thermometer to the centigrade scale, subtract 32 and multiply by $\frac{5}{9}$.

***

(283) Will you kindly advise me of a formula for making a writing ink which will, after a few days, fade or evaporate from the paper on which it is written. I desire the information, to use in experimenting, and should you be unable to furnish it, I would appreciate anything you could do to help me to that end. L. A. H., Savannah, Ga.

Ans.—There is an ink used in France which consists of an aqueous solution of iodide of starch, which will disappear within four weeks after using. Another ink which will appear black at the time of writing, but which will disappear within 24 hours, is made as follows: Boil nutgalls in alcohol, add copper sulphate and sal ammoniac, and when cold dissolve a little gum in it.

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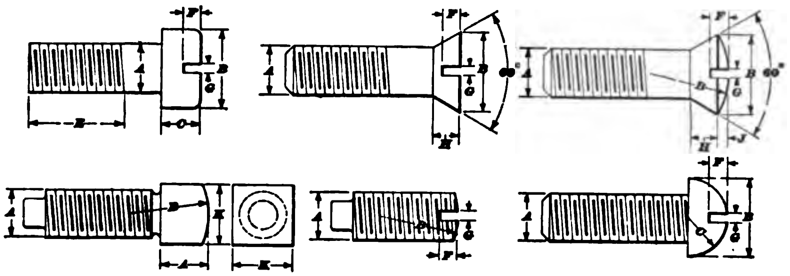
(284) Please inform me where I can buy carbonic acid gas for use in connection with a soda fountain. L. J. K., Kinder, La.

Ans.—From any of the following concerns: Bissell Chemical Co., McKeesport, Pa.; Charles Cooper & Co., 194 Worth Street, New York; Hecla Compressed Gas Co., Chelsea, Mass.; Liquid Carbonic Acid Mfg. Co., 76 Illinois Street, Chicago, Ill.

DIMENSIONS OF

ROUND HEAD AND SET SCREWS



A	B About $1.5A+\frac{1}{8}''$	C About $\frac{B}{2}$	D $C-\frac{1}{32}''$ or $C-\frac{1}{16}''$	E About $1.5A+\frac{1}{8}''$	F About $\frac{C}{2}$	G About $\frac{F}{2}$	H $.866(B-A)$	J $.134B$	K $A+\frac{1}{16}''$ or $A+\frac{1}{8}''$
Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch
$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{5}{32}$	$\frac{5}{8}$	$\frac{3}{32}$	$\frac{3}{64}$	0.108	0.040	$\frac{3}{8}$
$\frac{5}{16}$	$\frac{7}{16}$	$\frac{7}{32}$	$\frac{3}{16}$	$\frac{11}{16}$	$\frac{3}{32}$	$\frac{3}{64}$	0.108	0.059	$\frac{3}{8}$
$\frac{3}{8}$	$\frac{9}{16}$	$\frac{9}{32}$	$\frac{1}{4}$	$\frac{13}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	0.162	0.075	$\frac{1}{2}$
$\frac{7}{16}$	$\frac{11}{16}$	$\frac{11}{32}$	$\frac{5}{16}$	$\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	0.217	0.092	$\frac{1}{2}$
$\frac{1}{2}$	$\frac{13}{16}$	$\frac{13}{32}$	$\frac{5}{16}$	1	$\frac{3}{16}$	$\frac{3}{32}$	0.270	0.109	$\frac{5}{8}$
$\frac{9}{16}$	$\frac{15}{16}$	$\frac{15}{32}$	$\frac{3}{8}$	$1\frac{1}{16}$	$\frac{3}{16}$	$\frac{3}{32}$	0.325	0.126	$\frac{5}{8}$
$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{9}{16}$	$\frac{1}{2}$	$1\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{8}$	0.379	0.143	$\frac{3}{4}$
$\frac{3}{4}$	$1\frac{5}{16}$	$\frac{5}{8}$	$\frac{9}{16}$	$1\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	0.487	0.176	$\frac{7}{8}$
$\frac{7}{8}$	$1\frac{7}{16}$	$\frac{3}{4}$	$\frac{11}{16}$	$1\frac{9}{16}$	$\frac{5}{16}$	$\frac{5}{32}$	0.487	0.193	1
1	$1\frac{11}{16}$	$\frac{7}{8}$	$\frac{13}{16}$	$1\frac{3}{4}$	$\frac{5}{16}$	$\frac{5}{32}$	0.595	0.226	$1\frac{1}{8}$
$1\frac{1}{8}$	$1\frac{15}{16}$	1	$\frac{15}{16}$	$1\frac{15}{16}$	$\frac{3}{8}$	$\frac{3}{16}$	0.703	0.260	$1\frac{1}{4}$
$1\frac{1}{4}$	$2\frac{1}{16}$	$1\frac{1}{16}$	1	$2\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{16}$	0.703	0.276	$1\frac{3}{8}$
$1\frac{3}{8}$	$2\frac{5}{16}$	$1\frac{3}{16}$	$1\frac{1}{8}$	$2\frac{5}{16}$	$\frac{7}{16}$	$\frac{7}{32}$	0.811	0.310	$1\frac{1}{2}$
$1\frac{1}{2}$	$2\frac{7}{16}$	$1\frac{1}{4}$	$1\frac{3}{16}$	$2\frac{1}{2}$	$\frac{7}{16}$	$\frac{7}{32}$	0.811	0.327	$1\frac{5}{8}$
$1\frac{5}{8}$	$2\frac{11}{16}$	$1\frac{5}{16}$	$1\frac{1}{4}$	$2\frac{11}{16}$	$\frac{1}{2}$	$\frac{1}{4}$	0.920	0.360	$1\frac{3}{4}$
$1\frac{3}{4}$	$2\frac{7}{8}$	$1\frac{7}{16}$	$1\frac{3}{8}$	$2\frac{7}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	0.974	0.385	$1\frac{7}{8}$
$1\frac{7}{8}$	$3\frac{1}{16}$	$1\frac{1}{2}$	$1\frac{7}{16}$	$3\frac{1}{16}$	$\frac{9}{16}$	$\frac{5}{16}$	1.02	0.410	2
2	$3\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{9}{16}$	$3\frac{1}{4}$	$\frac{9}{16}$	$\frac{5}{16}$	1.08	0.435	$2\frac{1}{8}$
$2\frac{1}{4}$	$3\frac{5}{8}$	$1\frac{13}{16}$	$1\frac{3}{4}$	$3\frac{5}{8}$	$\frac{9}{16}$	$\frac{5}{16}$	1.19	0.486	$2\frac{3}{8}$
$2\frac{1}{2}$	4	2	$1\frac{15}{16}$	4	$\frac{5}{8}$	$\frac{3}{8}$	1.29	0.536	$2\frac{5}{8}$
$2\frac{3}{4}$	$4\frac{3}{8}$	$2\frac{3}{16}$	$2\frac{1}{8}$	$4\frac{3}{8}$	$\frac{5}{8}$	$\frac{3}{8}$	1.40	0.586	$2\frac{7}{8}$
3	$4\frac{3}{4}$	$2\frac{3}{8}$	$2\frac{5}{16}$	$4\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	1.51	0.636	$3\frac{1}{8}$

SCIENCE AND INDUSTRY

Vol. VII | November, 1902 | No. 11

ENGINEERING OF POWER PLANTS—I

W. B. GUMP, JR., A. S. M. E.

Location and General Arrangement

THE subject of power-plant engineering covers so broad a field that in order to make an article on it of practical value it must be limited to a general outline, presenting such details as concern the majority of engineers, and pointing out such problems as are commonly met in practice.

In dealing with the power plant we shall present its different features in the following order: (1) location and general arrangement, (2) mechanical equipment, (3) electrical equipment, (4) railway plants.

Power plants may be classified under two general heads: central stations and isolated plants. This is a very general classification and must be subdivided according to the kind of power, and the system employed. It is usual to think of the central station as one supplying light and power to a city or to a railway line, and the isolated plant as a plant located in a single building and supplying power to that building.

Very often, however, we find a plant supplying a large number of factory buildings, and in its system and equipment it is identical—or nearly so—with the central station. We cannot therefore draw too definite a line in our classification.

Central stations may be subdivided more specifically into lighting plants and power plants. In many cases we find a station supplying both light and power. A plant of the latter class is more often a railway plant, either city or suburban. As to the motive power employed, plants may be classified as steam and hydraulic.

The isolated plant is, almost without exception, operated by steam, since a plant employing hydraulic power of any consequence would, by reason of its environment, make extensions and become a central station for electric transmission of power. An exception to this would be in the case of a mill or small factory located on a river or canal, where the head is limited, and thus the water power confined to its immediate locality.

Since the present description is to deal with the problems concerning the location of a plant, let us now analyze some of the conditions which confront the engineer who has been called upon to locate and design a power plant. Among the most important things he must consider are (1) the purpose of the plant, (2) railway or water facilities for transporting fuel, (3) water supply for condensers and boilers, (4) probable increase in the amount of power required, (5) expense of land and taxes on property to be chosen for the site, (6) condition for good foundations. It is evident from the items just mentioned that no set rule can be

stipulated, the matter depending upon the judgment of the engineer or others in charge, who must from experience be able to decide upon a location which meets each of these conditions without any serious drawback. It would not seem at first thought so much of a difficulty to decide upon a suitable location after carefully weighing these conditions, which of course, are purely local; the task is by no means an easy one, however, and must be determined by those having large experience in such work. The reference made to determining the location does not apply to the isolated plant, as in most cases the location is not much of a problem, but it is the city central station or the large transmission plant on which the statements just given have a special bearing.

In order to give a general illustration let us consider a probable case of a lighting and power plant which is to be built for a town of say 10,000 inhabitants; this town we shall suppose is fifty miles from any larger town, but has good railroad facilities, and is on a small river. It is evident that the plant will have to be operated by steam, so that the next question that comes up concerns the fuel facilities. The railroad can bring all of the necessary fuel, and the river can furnish feedwater for the boilers and cooling water for the condensers. The plant should, therefore, according to general conditions, be located at a point common to both the river and railroad, if such can be found. If, however, the ground at this point should be formed of quicksand or soft clay, the selection of a site at a more remote point would be necessary. It is often advisable to make a definite plan based on the amount of power and light required for the different districts of the locality, and the time of day and duration that each portion of power is supplied. In this way a fairly accurate load curve may be constructed, which will show in black and white the conditions to be met. From such a curve the costs may be figured, and a more satisfactory financial basis may be reckoned.

It is well to state here that there is no better way to picture the conditions of any problem relating to power than through a plotted curve, and it is not only advisable, but, as a rule, necessary, in order to predetermine as nearly as possible the true situation of things.

It must be emphasized here that the plant, when completed, according to the most accurate specifications, will be subject to many changes from time to time, due to the growth and demands of the community, and it is the growth of the plant which must be kept well fixed in mind at the outset. Otherwise much trouble and inconvenience may be caused, such as having to tear down brick walls or rip out good piping, in order to put in another boiler or an extra dynamo, just because the plant was built with only enough space to accommodate the first few consumers in the neighborhood.

In the case now being considered let us suppose that the town is a manufacturing town. It is then evident that there will be a demand for power. This should preferably be plotted on a separate curve from that of the lighting unless it is found that only small direct-current motors are to be used; these of course, would be operated from one of the lighting dynamos, on a 110- or 220-volt circuit. Suppose that a large factory at the opposite end of town from the plant desires to operate its entire establishment by electricity. The factory in question is say four miles distant from the plant. A new problem now presents itself, and the ques-

tion of transmitting by alternating current must be considered. If the power were supplied over such a distance by direct current the drop, and hence the loss, would probably be too great to make direct-current transmission feasible on account of the cost of copper conductors. The only thing to decide upon then is alternating-current transmission. This having been decided the question of the voltage to be used would next present itself. This would have to be decided according to the amount of power required by the factory, the most economical maintenance of apparatus, and the consideration of safety to human life.

In this case the voltage would probably be stepped down through a rotary transformer or be stepped down directly to a synchronous motor as the prime mover.

Since a decision has been made to use alternating current, there is no special reason for using any direct-current apparatus, since lighting may be accomplished successfully at the present time by alternating current.

In this connection it is not out of place to mention the constant-current transformer now coming into prominence for street lighting. It has several distinct advantages, among them being a considerable saving in the first cost of installation compared to purchasing an arc-light dynamo and less attention is required for the operation of the former.

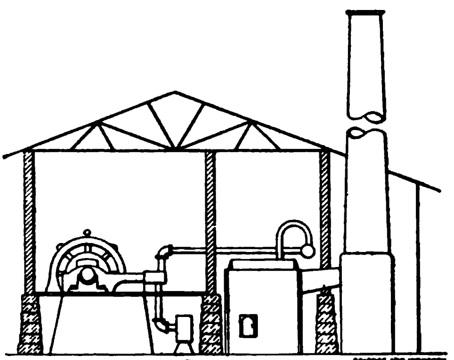


FIG. 1

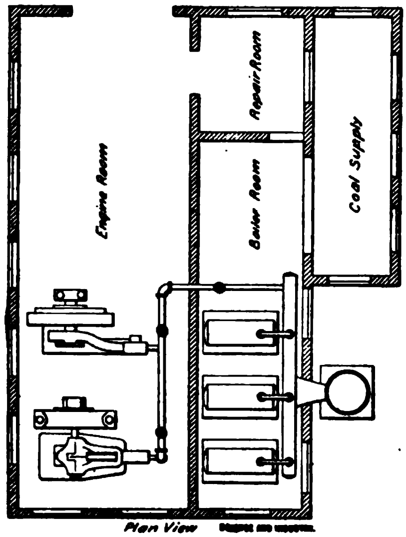


FIG. 2

These points will be considered more in detail later.

It is not unlikely that as a town of this kind grows an electric-railway line will be built connecting it with one or more neighboring towns, and in case the plant in question is to furnish power for a railway line there will be practically a new plant to be designed. The conditions which will determine the size of engines and generators to be installed are many and various, and will depend upon the probable growth of traffic. The latter problem of the railway plant is more difficult in its details than the city plant and will be taken up in detail in another paper.

Supposing that the capacity of the plant has been figured to a fairly accurate degree, we are now prepared to form some definite idea as to the size of the building required. In all probability the plant will be more than 1,000 H. P., not considering extensions for railway power, and the building

must have ample room to install additional machinery as demands upon the plant increase.

About the best general arrangement for all plants is a rectangular building with the engines placed side by side, the extensions being made by increasing the number of units toward the distant end of the rectangle. This is shown in the accompanying figures, and is the arrangement adopted in the majority of modern plants. The building for a plant is almost universally of brick and should be well constructed. It should have a firm foundation and the machinery should be placed at a height which will insure its being protected from dampness. A great many plants have a cemented basement in which the condensers and pumps are placed, the cement floor serving both to keep moisture from the machinery and to furnish space for placing some of the other accessories which are not injured by moisture.

The foundation of the building will depend upon the character of the soil, and a most careful investigation of its nature is of the utmost importance. The construction of the building comes within the province of the architect rather than the engineer; at the same time the building for a power plant is used for a special purpose and the engineer as well as the architect should know enough concerning it to be on the safe side, since an error in building may cause a great deal of unnecessary expense in the end.

In the case of an isolated plant, the machinery usually takes up only a portion of the basement; the space is given and all the engineer needs to consider is the apparatus to be used. The principle points to be considered here are (1) sufficient space for the convenient arrangement of machinery, (2) ventilation, (3) light, (4) freedom from dampness.

In regard to the size of building required for a power plant such as was mentioned in the foregoing, it may be stated as a general rule that the building should be large enough to allow of increase in the capacity of the plant to at least four times the size of the original installation. In many cases, lighting plants have doubled their capacity each year for several years, so the necessity of plenty of space is readily seen.

Attention should be called to the fact that a brick wall between the boiler and engine rooms is the plan universally adopted. The reasons for this need not be discussed, as it is obvious that the engine room and boiler room should be separated by a strong partition. The main reason for this is that there is less damage from boiler explosions; besides this the coal dust and dirt from the boilers is kept away from the working parts of the machinery.

If possible there should be provision for a traveling crane in the engine room, as in erecting and changing machinery and making additions it will be found of great assistance. This is included in the mechanical equipment which will be treated in another paper; it is mentioned here as a general feature of all plants above 500 H. P. capacity.

The next point of importance is that of making the proper provision for the supply of coal. It was stated that a plant should be at close proximity to a railroad or river in order to convey the coal to the plant with the least amount of handling. Where a plant cannot be built right on a main line it is then necessary to run a spur over from the main line so that the coal may be dumped directly into

the coal pit from the cars. The capacity for coal should be large enough to supply the boilers for at least 30 days without interruption, and many plants contain a larger supply.

On account of the convenience to coal supply, a good many plants have been built near coal mines, and in such cases the power is transmitted by means of a high-tension alternating-current system and stepped down through transformers at the receiving end, which in almost all cases is several miles distant from the mine. This method has the advantages of coal supply, and it also confines the coal dust and smoke to one locality. The distributing point contains the electrical apparatus only, and for this reason is much cleaner than any other arrangement would permit.

In large plants of from 10,000 H. P. upwards, it becomes necessary to employ some sort of mechanical conveyers for handling the coal. This will be taken up in the paper on the mechanical equipment.

The description thus far relates entirely to steam plants; we shall now consider some of the important features of the hydraulic plant. One of the best examples of this class is the great Niagara Falls plant. The general advantages of hydraulic power are at once evident. In the first place there is a continual supply of mechanical energy which only needs one conversion to change it to electrical energy; the efficiency is, therefore, much higher than can be obtained from coal burned under a boiler, the latter method requiring two transformations instead of one.

Hydraulic power is directly proportional to the head of water, the volume being constant. In most hydraulic plants the power is communicated to a turbine which is usually directly connected to the generator. A good many of the plants in the West are located on streams which are subject to great variations in level during different seasons of the year. This condition must be kept in view when the plant is designed, and provided for as far as its equipment will permit.

As to the arrangement of apparatus pertaining to hydraulic plants no fixed rule can be given since the entire equipment will depend upon local conditions.

There are three things which determine the location of a plant employing water power: (1) maximum head of water, (2) condition for solid foundation, and (3) accessability. When weighing these conditions it has sometimes been found necessary to make a sacrifice in the amout of head in order to obtain the best foundation. It is obvious that the former may be sacrificed if it is for the betterment of the latter, but the converse does not follow.

The necessity of having firm foundations is the most important feature of such a plant, and the very best of hydraulic masonry is none too good, even if the site is such as to prevent less than the maximum fall of water given by the steam.

In concluding this description it is well to add that a power plant is not complete without some sort of a repair department. The size and equipment will necessarily depend upon the character and capacity of the plant, and should be fitted up to meet emergencies, for they are bound to happen at some time or other. The important point to bear in mind is that *the plant must run;* hence it is evident that the proper tools at hand for a quick repair will more than pay for themselves in a comparatively short time.

(*To be continued.*)

THE STEAM LOOP IN THEORY AND PRACTICE

W. H. WAKEMAN

An Explanation of Its Utility in Steam Plants Under Various Conditions, Also of the Principles on Which It Operates—Conditions Necessary for Its Successful Operation, and Defects to be Avoided in Design and Construction

THE steam loop is undoubtedly the most simple device used by engineers to return hot water resulting from the condensation of steam, to the boilers without loss, except the expenditure of heat that is actually required to do the work, and that is so small as to be unworthy of serious consideration. It is not intended to separate water from steam, neither does it form any part of the apparatus required for this purpose, as it only takes water that is very hot and

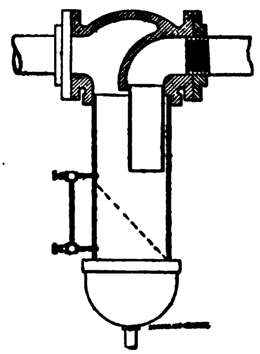


Fig. 1

puts it back into the boilers to be evaporated and used over again.

If we take the case of an ordinary plant, the main steam pipe usually conveys steam and water to the engine. The presence of water is due to priming in the boiler, or condensation after the steam has begun its journey, and as its presence is objectionable, a separator, shown in Fig. 1, is installed to remove it. This particular kind of separator consists of an ell turned downward so as to discharge into a reservoir, out of which dry steam issues and passes on to its destination.

Steam will not flow from one point to another in a system of pipes, valves, etc., unless there is a difference of pressure between the two points; the pressure existing at the outlet of this separator is less than is found at the water-line of the boiler, consequently, if they are both on the same level, and connected by a drip pipe, the water will not flow back into the boiler, but the tendency will be to flow in the opposite direction.

If the outlet of a separator is high enough to afford a column of water, the weight or pressure of which per square inch is equal to the difference in pressure already mentioned, the system will be in equilibrium, and the water will stand still. The height of this column may be found as follows: Suppose that the water weighs but 59 pounds per cubic foot owing to the heat which reduces its density. By dividing this weight by 144 we find that a column 1 inch square and 1 foot high weighs .41 pound, which becomes the constant for water at this weight. If the difference in pressure is 6 pounds per square inch, by dividing 6 by the constant we find that the column must be 14.6 feet high. This is illustrated in Fig. 2, where the pipe to the boiler is shown full of water.

This will not give satisfaction in practice (nor is it theoretically exact), because the column of water must be heavy enough to cause it to flow into the boiler, and as a check-valve is usually considered necessary, also a stop-valve, the friction will be increased; therefore, it will be necessary to add

25 per cent. to the height of the separator above the water-line, making the whole 18.2 feet, as illustrated in Fig. 3.

The additional 25 per cent. in height amounts to 3.6 feet, and multiplying this by the constant .41 shows that when the pipe is filled with water the weight or pressure per square inch is nearly 1.5 pounds above boiler pressure at the water-line, which is sufficient to discharge the water into the boiler, where the piping is laid out so as to avoid undue friction.

I have not stated the boiler pressure carried, because it makes no difference whether it is 10 or 100 pounds, except when determining the weight of water per cubic foot, as it is the difference in pressure, as already stated, with which we must deal.

It is seldom convenient to locate a separator so high above the water-line,

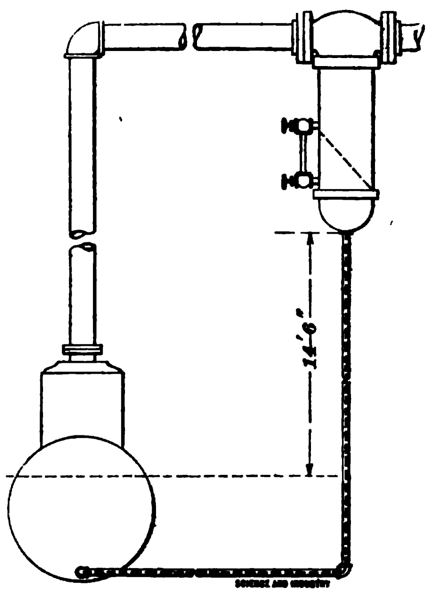


FIG. 2

especially if vertical boilers are used; therefore, it becomes necessary to devise a plan for raising the water discharged from the separator to a height that will afford the pressure necessary to make it flow back into the boiler, and this work the steam loop is designed to do in an efficient way.

Fig. 4 illustrates a plant where the

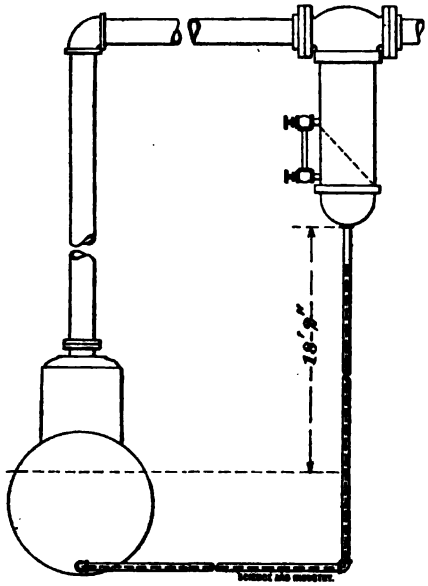


FIG. 3

engine is below the water-line of the boiler. When designing an apparatus of this kind the first point is to determine the required height of the vertical pipe near the boiler, and this will depend on the difference in pressure, as already explained in detail.

This pipe will hereafter be referred to as the "drop leg," and when its height is fixed, the other pipes will naturally be arranged to connect with it as shown. The vertical pipe over the engine is called the "riser," and this discharges into the horizontal pipe through the goose neck, in order to prevent water from returning to the separator.

The thoughtful student may wonder how this arrangement of piping can be made to work and give satisfaction, because it appears as if the water in the riser would go no higher than

it stands in the drop leg, hence there could be no circulation. This would be true, provided the riser contained a solid body of water, but it does not. It carries a mixture of water and steam, the specific gravity of which is very much less than water, which allows it to operate for the following reason: Condensation in the horizontal pipe reduces the pressure at this point, and this causes the water and steam to rush upward until they

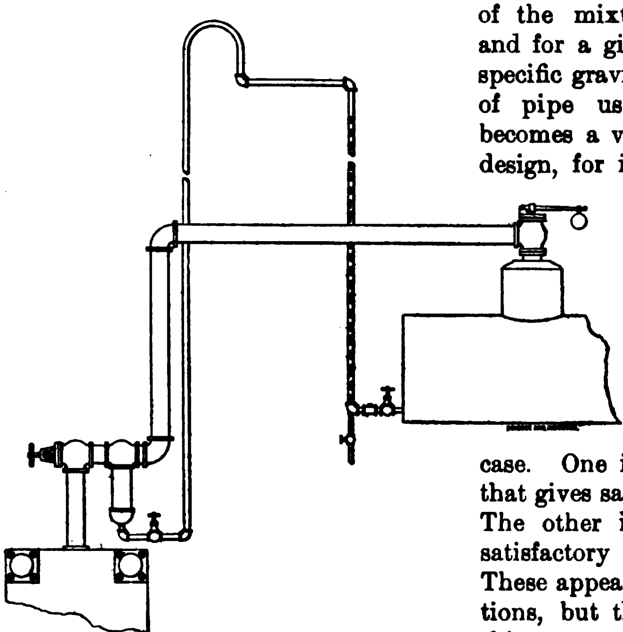


FIG. 4

are discharged through the goose-neck connection.

The next point to claim attention is the greatest distance that can be allowed from the riser down to the outlet of the separator, as illustrated in Fig. 4. If condensation in the horizontal reduces the pressure 3 pounds, by dividing this difference by the constant .41 we find that it represents a vertical height in the riser of 7.3 feet, assuming that a solid column of water ascends the riser, but in reality it is a mixture, the specific gravity of which will probably not be more than one-fifth that of the hot water; therefore, it will support a column five times as high, making it 36.5 feet, or $36.5 - 18.2 = 18.3$ feet below the water-line of the boiler. This is correct for the assumed conditions, but the whole calculation is on a very conservative basis, so that in many cases this distance may be increased. It depends upon the specific gravity of the mixture ascending the riser, and for a given quantity per hour the specific gravity depends upon the size of pipe used; therefore, the latter becomes a very important point in the design, for if the separator is 18 feet below the water-line, and the pipe comprising the riser is so small that the specific gravity is greatly increased, the apparatus will fail to work.

There are two ways of determining the size of pipe required in such a case. One is to find a similar plant that gives satisfaction, and duplicate it. The other is to experiment until a satisfactory arrangement is secured. These appear like very indefinite directions, but there is one good point in this connection, viz., there is little or no danger of getting the pipe so large that it will not work; but it may easily be made too small. If an 8-inch pipe is used to supply steam for an automatic engine developing 500 horsepower, the riser should be made of $1\frac{1}{4}$-inch pipe.

So far as the ordinary steam plant is concerned, there is practically no limit to the distance that may be allowed between the separator and the boiler, but it should be remembered that where they are 500 or 1,000 feet apart, there will probably be several

pounds difference in pressure between the two points, and allowance must be made for this when the height of the drop leg is fixed, in order to insure successful operation.

In such a case the riser must be located near the separator, as shown in Fig. 5. The horizontal is then made a proportional length and, connected into the drop leg; then a pipe of the length necessary to connect with the boiler is laid horizontally, completing the job.

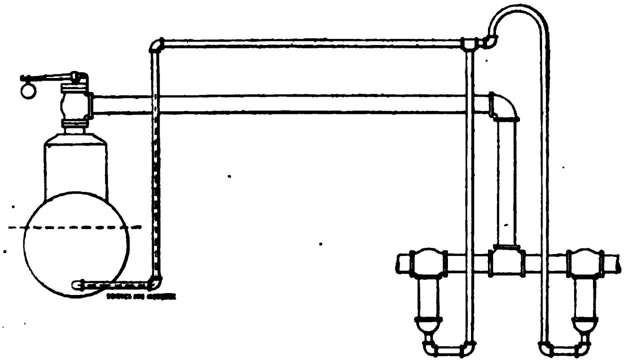


FIG. 6

Fig. 6 shows a job that is not properly designed. Two risers are connected into one horizontal, which is made twice as long as it would otherwise be in order to compensate for the extra work put upon it. This is wrong, because it is quite possible for the pressure in one riser to be less than in the other, thus causing water from it to be discharged into the other separator, instead of going to the drop leg.

Of course, this could be prevented by a judicious use of check-valves, but

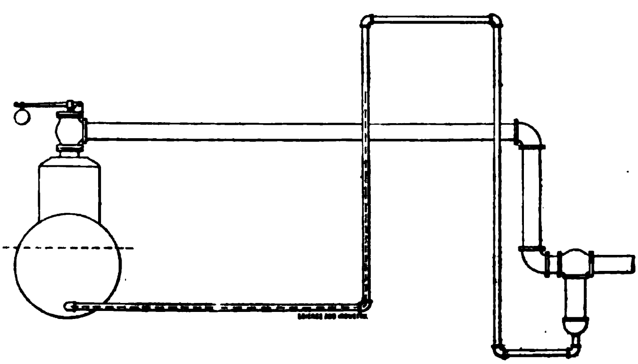


FIG. 5

such complications are undesirable, as the system should be made as simple as possible, and also because uncalled for valves do not always overcome the objections to a badly designed system.

Fig. 7 shows the correct way to connect for two steam loops that are intended to discharge into one boiler, as the risers and horizontals are made separate, while the two drop legs discharge into one common feed-pipe.

Fig. 8 illustrates one steam loop, taking the condensation from a separator, and another taking it from a steam-heating coil, while both discharge into the same boiler. This arrangement can be made to work satisfactorily if the forgoing directions and suggestions are observed.

It will be noted that in all of the illustrations here presented, the feedpipe from the steam loop enters the boiler independently of all other feedpipes. This is not an accidental plan but one that must be observed if the best results are desired, for if a pump discharges into the same pipe, the pulsation caused by its intermittent action will interfere with the steam-loop discharge.

After a system of piping that is drained by one or more steam loops has been shut down (with steam on the boilers) long enough to allow all the

pipes to become filled with water, it is not reasonable to expect it to work well again until measures are taken to

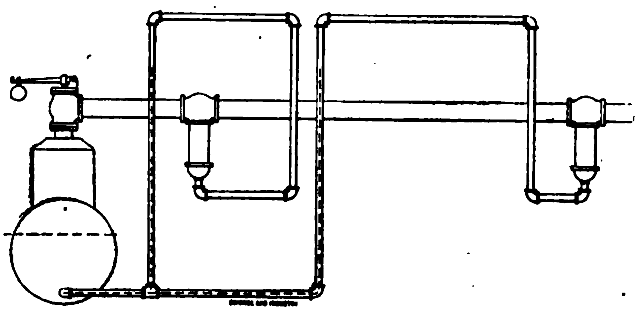


FIG. 7

entirely remove the water of condensation from the main supply pipes, and from the risers.

At other times air may collect in the top of the risers, or in the horizontals and cause trouble. A small valve should be connected at each of these points, so that it may be opened under pressure, and the air blown out. If it is desired to make this operation automatic, air valves may be used at these points, so that as soon as air begins to collect, the cooling process will cause contraction which opens them, allowing the objectionable air to escape. When steam begins to pass out, the heat causes expansion which closes the valves and prevents further loss from this source.

The following calculation shows the power required to operate a steam loop under given conditions: Suppose that three boilers are in use, developing 100 horsepower each, and evaporating 9,000 pounds of water per hour into dry steam. An additional 5 per cent. of water passes out with the steam, without being evaporated, amounting to 450 pounds per hour. The difference in pressure is 20 pounds, and dividing this by the constant .41, for reasons already explained, and adding 10 per cent. to overcome friction, shows that the water will be raised 53.9 feet high, developing $450 \times 53.9 = 24,255$ foot-pounds per hour, which is equivalent to .0122 horsepower. The steam loop is not an economical way of developing power, but if we admit that it takes twice as much steam as the most economical pump, it is equal to only .025 horsepower, so that the whole amount is too small to be worthy of serious consideration.

In some places where the difference in pressure amounts to 25 pounds or more, it may not be convenient to erect a drop leg high enough to overcome the difference in pressure, but in high buildings that are fitted with air shafts, it can easily be accomplished, and there are few shops or factories where the necessary pipes cannot be

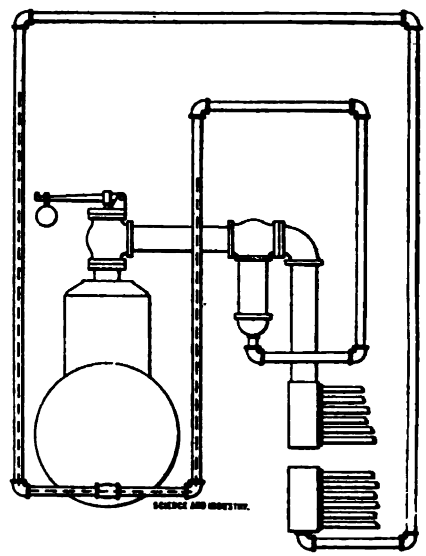


FIG. 8

run through the rooms until the required height is secured. In such cases it will not be necessary to add 25

per cent. to the height in order to overcome friction, as 10 per cent. will be sufficient. It is not always so easy to tell whether a steam loop is working or not, as in the case of a pump or an injector, but if it fails to operate the horizontal will soon become cool and thus indicate the failure.

The fact that it contains no moving parts is a point in its favor, because it will last indefinitely, and its first cost is very low, compared with other apparatus used to do the same work, and it requires little or no attendance.

It possesses a very great advantage over a steam trap discharging into the sewer, as it not only saves heat but puts pure water into the boilers, thus preventing the formation of scale, so far as the returning water is concerned.

LARGE WATER-POWER PLANTS

THE Niagara Falls Power Company, at Niagara Falls, N. Y., shunts a portion of the water of the Niagara River around the falls by means of an inlet canal about 1,200 feet long, 250 feet wide at its mouth, and 12 feet deep; two wheel pits, each about 463 feet long, 180 feet deep, 20 feet wide, and a discharge tunnel with horse-shoe shape cross-section, 21 feet vertical diameter, 18 feet 10 inches largest horizontal diameter, and 6,890 feet long. Extension into wheel-pit No. 2 is $545\frac{5}{10}$ feet long. Average depth below surface, 200 feet.

Average head of water, 136 feet; each turbine discharging 430 cubic feet per second; separate penstocks, 7 feet 6 inches diameter; turbines connected direct to alternators by vertical tubular steel shafts, 38 inches in diameter.

The installation in power-house No. 1 consists of 10 twin turbines, each of 5,000 H. P.; two-phase, 2,200 volts, 25 cycles, 250 revolutions per minute; and power-house No. 2 will contain 11 similar units.

The current here generated is transmitted to Buffalo, Tonawanda, and Lockport at 22,000 volts, three-phase, by three overhead transmission circuits, two of copper and one of aluminum conductors; each circuit about 22 miles in length. Most distant substation in Buffalo, 31.4 miles from the power-house.

Thirty thousand H. P. is distributed locally, mainly on the power company's lands within two miles of the power-house, by means of 2,200-volt two-phase and 11,000-volt three-phase underground circuits.

Fourteen miles from Bakersfield, Cal., is the plant of the Power Development Company, of San Francisco, where water from the Kern River is led through a tunnel cut in solid granite a distance of 8,484 feet, with a cross-section of 6 ft. 4 in. $\times$ 6 ft. 4 in., and having a capacity of 321 cubic feet per second. This tunnel terminates in a forebay within the mountain, and from there is conducted by a water pipe 66 inches in diameter and 600 feet long to the wheels. The total fall is 210 feet. Flow of water (mean low) is 300 cubic feet per second.

The installation consists of three wheels (impulse type), one to each generator. Each wheel develops 750 H. P.; three generators of 450 K. W., 600 H. P. each; three-phase 60 cycles, 3,600 alternations, 500 volts.

The current is transmitted to Bakersfield 14 miles by a six-wire pole line at 11,500 volts. From substation here pole lines extend about 20 miles.—Power.

THE AMATEUR'S LABORATORY—II

R. G. GRISWOLD

RHEOSTAT AND GALVANOMETER

IN ORDER that the strength of a current may be varied at will within certain limits, it is necessary to insert in series with the source of supply a variable resistance. The instrument performing this function is called a rheostat, and, as described herein, has a total resistance of about 47 ohms through 150 steps of .313 ohm each. It has a capacity of 6 amperes and should not be forced to carry more. Fig. 1 shows the instrument complete.

The spool upon which the wire is wound is made of three circular pieces of hardwood, 6 inches in diameter by ½ inch thick, separated by two pieces 5 inches in diameter and ¾ of an inch thick. These five pieces are glued together, heated thoroughly in an oven to expel all moisture and given three coats of shellac. Prepare three ½-inch strips of thin asbestos paper equal in length to the circumference of the 6-inch circles, or about 18⅞ inches. Lay off a center line on two of them ¼ inch from the edge and running the entire length, and divide into ⅛-inch divisions. Wind these strips around the edges of the two outside disks and the unmarked one about the middle disk, cementing them in place with a light coat of shellac. The divisions of one strip should come exactly between those on the other, as shown by the dimensions in Fig. 2. Give the strips a coat of shellac.

The pins upon which the resistance coil is wound are ¾-inch wire brads, driven in the two outside disks at the eighth-inch divisions, allowing them to protrude about ⅛ inch. The coil is made of about 70 feet of No. 24 B. & S. soft-drawn bare German-silver resistance wire, wound from one pin to the next opposite consecutive one. To facilitate the work, fasten the spool in a vise and pass the loop made at one end of the wire by soldering (*b*, Fig. 2) over one brad. Then, while holding the wire very taut, pass it from one brad to the other. If the turns about the brads do not lie close to them, they may be made to do so by closing them with a pair of very sharp-nose pliers, easily made by grinding the ordinary kind to an edge at the end. When the last turn has been wound on, it is fastened by soldering to a small brass clip secured to the bottom disk *c*. Should an odd spacing of the brads bring this end to the top, fasten it there, bringing the end down through a hole in the spool to the under side, where it can be brought out in a small groove. It cannot be brought from the top to the binding screw on account of the brush arm.

The protruding ends of the brads should now be sent back over the wire loops, which will serve to tighten them, and the heads cut off with a pair of cutting pliers. Then carefully file the ends down until they are just above the wire and will not interfere with the arm. Wind two or three layers of shellaced thin paper strips, ¼ inch wide, over the wires just beside the brads, and on these strips wind very tightly several turns of No. 26 B. & S. spring brass wire for binding the wire loops in place in case they should become so heated as to expand enough to slip over the brads. Solder this binding wire at several places to keep the turns together and from slipping over on to the coil. Adjust the various wires where they pass the middle strip of

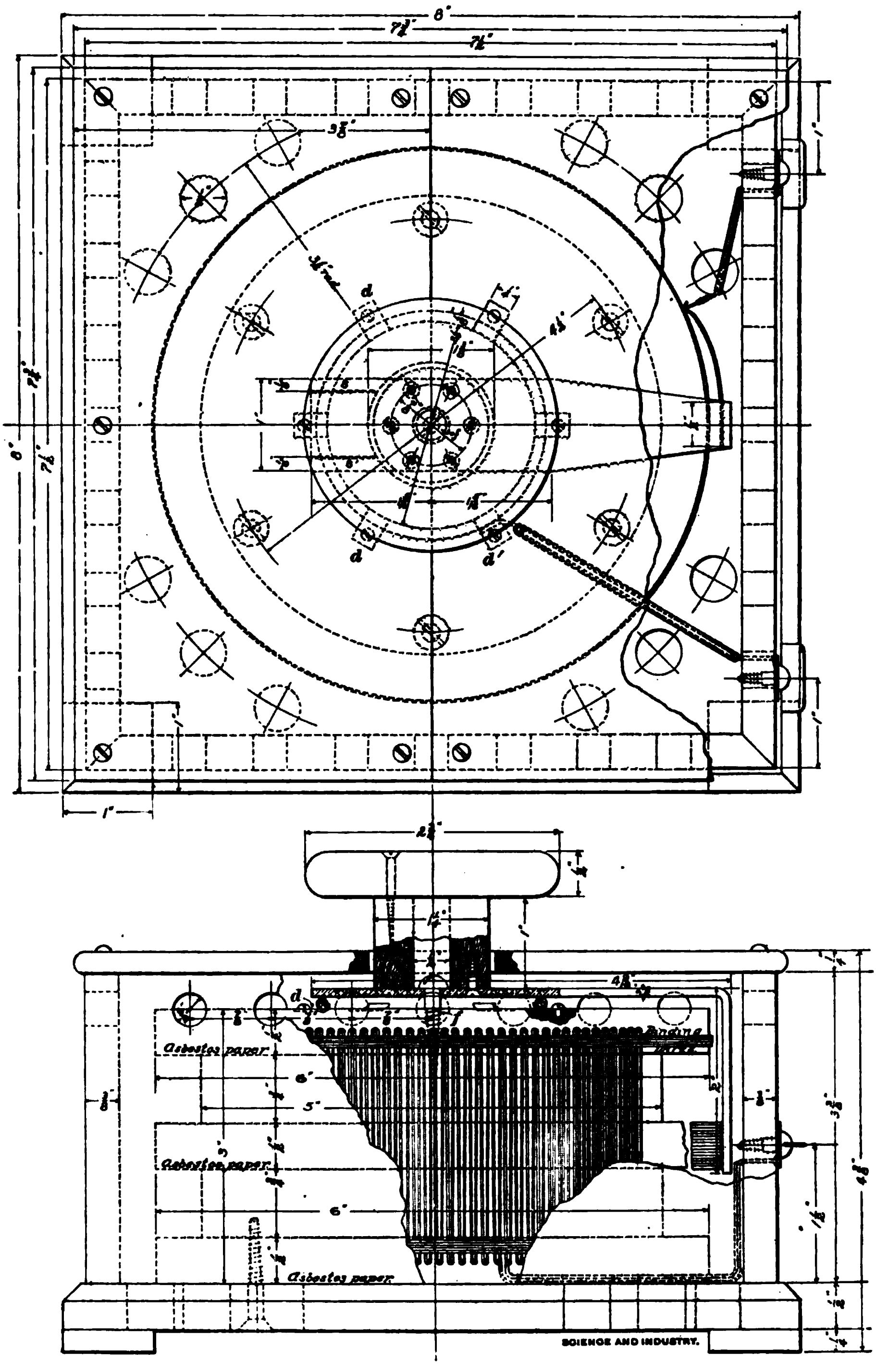

Asbestos paper
Asbestos paper
Asbestos paper
Binding
SCIENCE AND INDUSTRY.

FIG. 1

asbestos paper until the spaces between them are about even, and then give them a thorough coat of shellac, both at the middle strip and on the ends where they turn about the brads, where it should be well soaked in. Place in an oven and bake until perfectly dry, when a second coat should be given and baked. A piece of felt or hard cloth moistened with a little alcohol will remove the shellac from the surface of the wires where the brush makes contact, while that baked on the middle disk will hold them firmly in place where it passes over them.

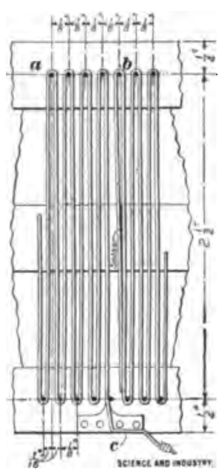


FIG. 2

The brush arm bears on a ring of $\frac{1}{8}$-inch hard brass wire, fastened to the spool by means of six small clips *d*, Fig. 1, soldered to it and set in recesses in the top so that the ring has a solid bearing. One of the connecting wires for the binding posts is soldered to this ring at *d*, carried down through a hole to a groove in the bottom and thence to the binding screw. The top of this ring should be slightly flattened and polished perfectly smooth.

The brush arm is made from a piece of $\frac{3}{32}$-inch sheet brass, carrying at its outer end a contact brush made of sixteen pieces of No. 32 spring brass or hard-drawn copper wire, about $1\frac{3}{4}$ inches long and bent as at *e*, Fig. 3, and soldered to the arm. Arrange these pieces so that they all lie in the correct position between two pieces of thick pasteboard, when they may be grasped with the pliers and held in position while being soldered to the arm. Bend the wires as shown so that they bear firmly on the coil wires, but not hard enough to displace them when moving. The bearing surface should be polished very smooth so that the brush will slide easily.

The construction of the hand wheel and stem is plainly shown in Fig. 1. The box should be made of well seasoned hardwood and provided with the ventilating holes shown. The feet on the bottom permit plenty of room for air to reach the bottom holes, and as the passage of the current heats the coil a circulation of air is established. After centering the spool on the bottom secure it in place with six screws, so adjusting the spool that the grain of the bottom disk and that of the bottom of the box cross at right angles to prevent warping. The top is made in two pieces so that the interior is accessible without removing the hand wheel. Bend the two sections of the brush arm *s* and *s′* slightly, to form a spring bearing on the wire ring, which will insure a firm contact and prevent binding at any part of the rotation. Adjust the pressure of the arm on the ring by means of the screw *f* until it turns smoothly, connect the coil to one binding post and the bearing ring to the other, and the coil is ready for service. The box may be finished in any desirable manner.

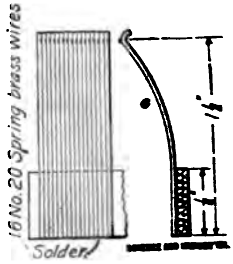


FIG. 3

This rheostat is not designed to carry a heavy current for any length of time, but simply to afford a means of quickly varying a resistance for experimental purposes, such as in the calibration of galvanometers where the adjustments of resistance are required in small steps.

In measurements of resistance by means of the Wheatstone bridge, to be described later, it is essential that the galvanometer used should be very sensitive, so that it may detect either the presence of an extremely small current or indicate the slightest variation in the strength of a current flowing. One of the most sensitive galvanometers which lends itself to easy construction is the astatic type, the magnetic system of which consists of two magnetic needles

It can be worked out to the best advantage with the fine saw described in the first article, and a file. The construction will be greatly facilitated if the form is divided on the line *a b* and then glued together after the two parts are completed. Give it one coat of shellac and see that the space in which the lower needle swings is smooth and free from hairs from the brush, pieces of lint, or other small obstructions that would interfere with the delicate action

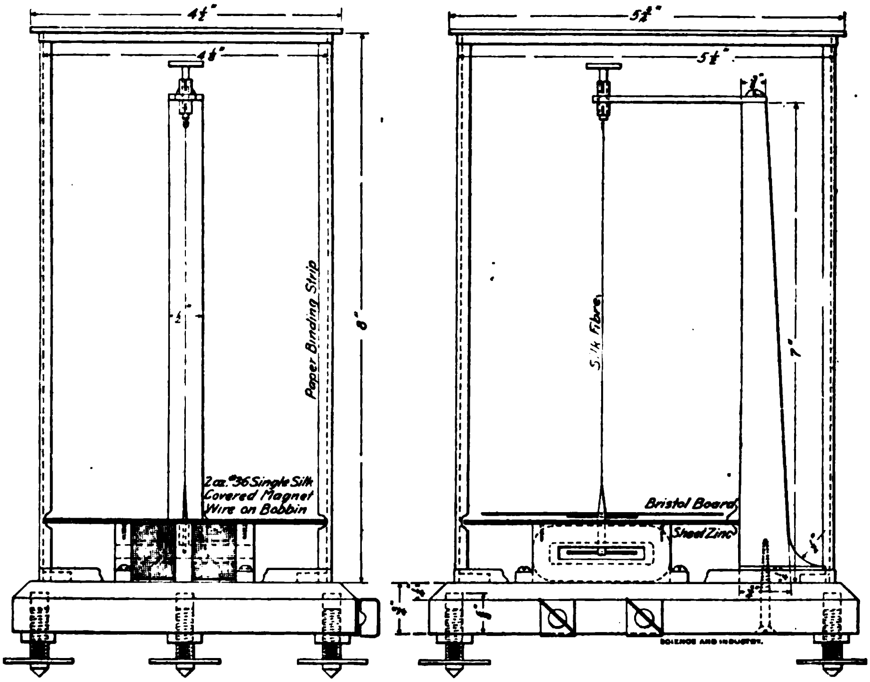


FIG. 4

rigidly mounted on one vertical axis, with poles reversed. Its sensibility depends upon three conditions: highly magnetized needles, small controlling force, and a large number of turns on the galvanometer bobbin. Two side elevations of this instrument are shown in Fig. 4, and a plain view in Fig. 5.

The bobbin, Fig. 6, upon which the wire is wound, should be made of some fine-grained hardwood, such as cherry.

of the suspended system. Wind the bobbin with 2 ounces of No. 36 single silk-covered magnet wire, winding one side full first and then the other, making the winding of one side a continuation of that of the other, so that the current will flow in the same direction around both coils.

Mount the coil upon the base, carrying the wires from the bobbin coil terminals down through holes to grooves

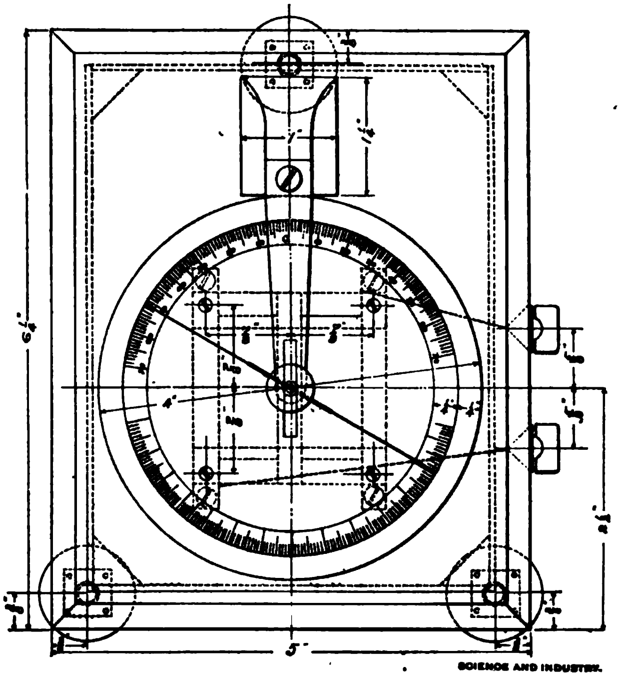


FIG. 5

cut in the bottom of the base, and thence to the binding screws on the side to the clips of which they are soldered. The dial is made by gluing a piece of thin white bristol board or other hard-surface paper to a piece of sheet zinc. After the dial is cut to size the circles and divisions should be drawn thereon, numbering the latter by tens. As the instrument is not intended for measuring by deflections in degrees, it is not necessary that the divisions have any particular value other than that they are equal. Fasten the dial to the bobbin by the screws shown so that the center of the dial coincides exactly with the center of the bobbin.

The vertical post is made of wood and has mounted at the top a brass arm, Fig. 7 (*a*), carrying at its end an adjustment device for the suspension fiber. A small piece of brass tubing which just fits the brass rod of the hook pin, is soldered in the end of the arm, and fine saw slits are cut at right angles in the top and bottom to permit a slight binding on the pin by squeezing them together slightly. The hook pin, Fig. 7 (*b*), should work smoothly, but be held with sufficient friction to stay in any position.

The magnetic system, Fig. 8(*a*), is composed of four very fine sewing needles and a glass fiber mounted between two very thin pieces of mica by means of shellac. Secure four of the finest sewing needles possible, and file off the points and heads until they are 1 inch long. Get from some chemist or druggist a small piece of small glass tubing, say 2 or 3 inches long. Heat about an inch of it in the middle in a gas flame until very soft and quickly pull it out at arms' length, which will result in a very fine thread of glass, from the thinnest straight portion of which cut a piece 3½ inches long. Cut a

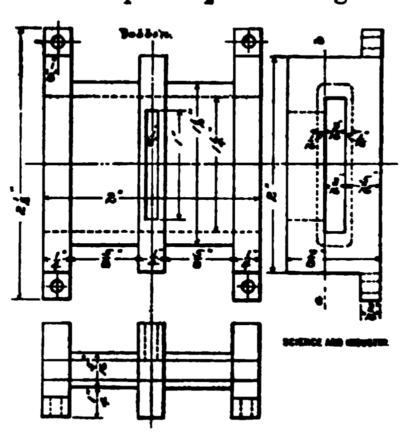


FIG. 6

small piece of mica to the shape shown at (*b*), Fig. 8, and with a very thin knife blade split off two very thin sheets. Draw the positions of the needles, glass fiber, and mica stirrup on a piece of white paper. Fasten one strip of mica to the paper in the position drawn, by means of a little wax or soap, and then lay the needles and glass fiber on the mica in their respective positions, having first put a small drop of shellac on the spots, where they cross the mica. Put a small drop of shellac on top of the needles and lay the remaining piece of mica on them, placing a small weight on it until the shellac has dried. Fasten the silk suspension fiber in the pointed end of the stirrup in the same manner, raising the lower side of the stirrup up by means of a piece of paper until the fiber is on a center line passing through the center of the needles. A small weight will serve to keep the two pieces of mica together until they have been firmly cemented to the fiber. Fig. 8 (*c*) shows the end view of this stirrup drawn to a larger scale.

The silk fiber can best be obtained from a wire-wound silk banjo bass string. By unwinding the wire from the string a long, fine fiber can be drawn out, which, being unspun, will have an equal torsional effect for either

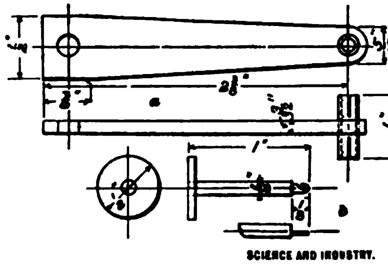


FIG. 7

direction of swing from the zero point. The balance of the silk, as well as the fine wire, should be wrapped on a card for future use.

The levelling screws, Fig. 9 (*a*), are made by forcing the unthreaded end of the screw into the disk *b*, soldering if necessary. The square

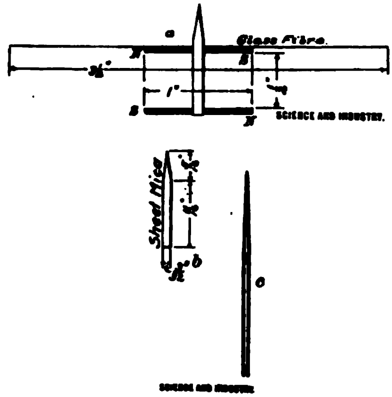


FIG. 8

piece *c* is threaded and fastened to the bottom of the base, ¼-inch holes being bored into the wood to accommodate the end of the screw.

The instrument being finished and assembled, it is now ready to receive the magnetic system. To magnetize the needles, make an electromagnet by wrapping about 100 turns of No. 22 magnet wire around a quarter-inch iron rod, 2 inches long. Touch the end marked *N*, Fig. 8 (*a*), of the upper set of needles with one end of the magnet for one minute while the current is passing, and then with the *same* end of the magnet touch the end marked *N* of the lower set of needles for the same time and with the same amount of current. This will strongly magnetize the needles so that the corresponding ends of the two sets will have opposite polarities, and as the north-seeking end of one set is almost if not quite counterbalanced by that of the other set, the directive force of the system will be very small.

Adjust the hook so that it projects equally on each side of the split tube. Insert the lower needles in the slot in

the dial and pass the fiber through the slot in the hook from the center outwards so that it will hang from the center of the rod and not from a point

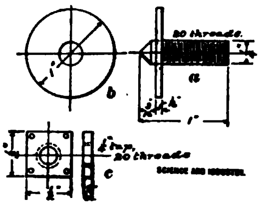


FIG. 9

outside of the center. Adjust the length of the fiber until the lower needles hang exactly in the center of the coils when looking through from the side and fasten to the hook with a small drop of shellac. As it is extremely difficult to make two sets of needles that exactly neutralize each other, one set will direct the system in a north-and-south direction and the instrument should be so placed that when the needle is at rest the pointer stands exactly over zero of the scale, and the axis of the coil has an east-and-west direction. The leveling screws will enable the galvanometer to be so adjusted that the pointer lies on both zeros of the scale and the center of the mica stirrup corresponds with the center of the dial. When the pointer is at rest on the zero division, give it a slight impulse and note whether it swings to the same division on either side of zero. If not, the fiber may have a slight twist which may be removed by turning the hook one way or the other until the deflections of the pointer are equal with respect to zero.

The galvanometer should now be provided with a glass case to protect it from dust and air-currents. This case is made from five pieces of clear window glass, bound together at the edges with strips of gummed, black paper such as used for binding magic lantern slides and passepartout pictures. Four small triangular blocks are glued to the base to prevent the case from slipping off. Great care should be taken to thoroughly insulate the bobbin wires where they pass through the base by making a small tube of paper to line the holes. Thoroughly coat the grooves underneath with shellac before the wires are put in and then give them a good coat. In instruments where such high resistance windings are used, small leakages of current that might occur across a moist surface or a thin layer of dust would so reduce the efficiency that proper indications will not be made. For this reason all places of probable leakage should be given good coats of shellac and baked, if possible. Shellac is one of the best insulators and is easily applied.

In connecting various electrical instruments together, much annoyance is caused by the stiffness of wires of sufficient cross-section to carry the current without appreciable loss. The connecting wires can be made of flexible lamp cord or several small copper wires, say No. 32 gauge, twisted together and insulated by winding tape around them. The ends should be soldered into a copper clip as shown in

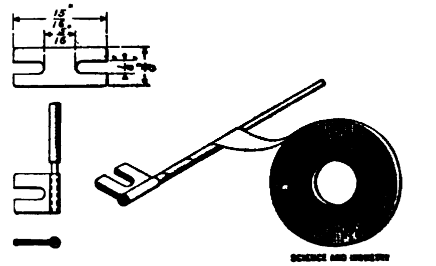


FIG. 10

Fig. 10, which is easily slipped under the head of the binding screw and insures good contact. If several of these connecting wires are made of

different lengths much time will be saved during experiments, in making connections.

A number of the clips may be made at once by clamping several pieces of sheet copper in a vise and working out the screw slots of all at the same time. Tin them on the inside of the bend before winding about the wire, by rubbing a hot soldering iron over the spot with rosin as a flux. Then tin the end of the wires. When the clip has been bent around the wire, squeeze it in the vise so as to make it lie close. Heat the tinned portion in a flame, when it will be firmly soldered to the wire. The tape may be secured from any electrical house or company for a few cents.

TEMPERATURE COEFFICIENT

THE resistance of any conducting body varies with changes in the temperature. The change of resistance per ohm with unit change of temperature is known as the temperature coefficient. Thus a piece of copper wire, which is known to have a resistance of 10 ohms at a temperature of 32° F., is found to have a resistance of 11 ohms at 77° F.

Variations in resistance due to variations of temperature often become quite important in practical work, and it may be necessary to make an allowance for a change in temperature. If R_o is the resistance of a piece of wire at 0° C. and a is the temperature coefficient of the substance, then if its temperature is raised from 0° to $t°$, its resistance has increased by $R_o \times a \times t$ ohms, and hence its resistance R_1 at $t° = R_o + R_o \times a \times t$. Then we have $R_1 = R_o(1 + a t_1)$. The resistance R_2 at $t_2°$ is similarly $= R_o(1 + a t_2)$. If R_o is not known, but R_1, t_1, and t_2 are known and it is desired to calculate the resistance R_2 at $t_2°$ then we have $R_2 = R_1 \dfrac{(1 + a t_2)}{(1 + a t_1)}$.

A sufficiently approximate and more convenient formula, for most purposes, that represents the effect of a change of temperature upon the resistance of a substance, is as follows:

$$R_2 = R_1 [1 + a(t_2 - t_1)]$$

If t_1 and t_2 are given in centigrade (C.) degrees, then a is the temperature coefficient per degree C.; if t_1 and t_2 are given in Fahrenheit (F.) degrees, then a is the temperature coefficient per degree F. If R_2 is the given resistance, then R_1 is obtained by dividing R_2 by $[1 + a(t_2 - t_1)]$.

As an example, suppose that a copper conductor, whose temperature coefficient is .00402 per ohm per degree centigrade, has a resistance of 15 ohms at a temperature of 20° C., what will be its resistance (a) at 50° C.? (b) at 8° C.?

SOLUTION.—(a) Let $R_1 =$ the resistance at 20° C., that is, $R_1 = 15$ ohms, $t_1 = 20°$, and $t_2 = 50°$ C. By substituting in the formula given, we get

$$R_2 = 15 [1 + .00402 (50 - 20)]$$
$$= 16.809 \text{ ohms.} \quad \text{Ans.}$$

(b) In this case, since 8° is less than 20°, $R_1 =$ the resistance at 8°, $t_1 = 8°$, $R_2 = 15$ ohms, and $t_2 = 20°$. It is now necessary to solve for R_1 in the formula. Doing this and substituting, we get

$$R_1 = \frac{R_2}{1 + a(t_2 + t_1)}$$

$$= \frac{15}{1 + .00402(20 - 8)} = 14.31 \text{ ohms.}$$

Ans.

A COUPLING REPAIR

CHAS. J. MASON

A Loose Cross-Key and How It Was Fixed—Designing a Reamer for the Bolt Hole. Details of Operation

IT WAS like this: the shaft had been gradually wearing out of line, in consequence of which the coupling bolts were subjected to a see-saw movement which soon loosened them to quite a degree; and not only this, but the cross-key also was influenced by this state of affairs to such an extent that it became loose, and under certain conditions, as to the load the engine was carrying, pounded unmercifully. Something had to be done, for aside from the annoyance of the continual pound, the longer it was allowed to run the worse it would become, until a serious breakdown would occur. Of course, no engineer wants such a thing to happen, and preparations were made to begin a repair.

The shaft in question was 13-inches in diameter, in two pieces, connected by a cast-iron coupling which was keyed on each piece of shafting. Across the face of each coupling was planed a keyway, of such a depth that when the key was introduced between them, they did not come together by $\frac{1}{4}$ inch. Tapered, reamed holes had been bored through coupling and key at both ends, and fitted bolts put in. These two bolts held the couplings together, or rather, against the cross-key and prevented it (the key) from flying out while the shaft was revolving. The key was intended to receive the torsional strain and so relieve the bolts, which without the key would have to perform a double service. In Fig. 1 is shown just how the coupling, key, and bolts were arranged.

It is not known whether the cross-key and bolts had originally been properly fitted in their respective places or not, but it is thought by those who had to do with the repair, that while the bolts may have been, the key had not. This opinion was based on the fact, that while the key remained tight in one coupling (that in which the nut end of the bolts were) it became loose in the other to the extent of $\frac{1}{8}$ of an inch. This threw the strain on that part of the bolts which was in the coupling with the enlarged keyway.

Owing to the variable and sudden loads which this shaft endured, the looseness of the key together with the shaft wearing out of line, soon began to affect the bolts and holes in which they were, that is, in the left-hand coupling as viewed in Fig. 1. The holes in that one coupling became enlarged to an amount equal to the looseness of the key, and the part of the bolt which was in it, became correspondingly smaller. The different illustrations in Fig. 1 show the conditions as they were at that time. At *A* is shown the coupling with key and bolts complete, as it was intended to be by the designer. *B* is the face view of the coupling showing the keyway and bolt holes. *C* is the original bolt, while *D* represents the bolt at the time of the repair. The enlarged keyway in the left-hand coupling is shown at *E*, face view, and at *F*, side view. *G* is a sectional view of one half of the coupling.

Now, to true up the distorted keyway (which would necessitate the raising up of that part of the shaft which had that coupling on, clear of its fellow), and fit a new key in, line the

shaft, and ream the holes to receive new bolts, was not to be thought of—much less done—in this particular case. So the next best thing to be done was put in operation; that which was best suited to the governing conditions.

Of course, a reamer had to be made, as one of the required size was not obtainable. So the engineer of the plant designed a reamer suitable for the work, being guided by the distorted holes as to how far the reamer must be

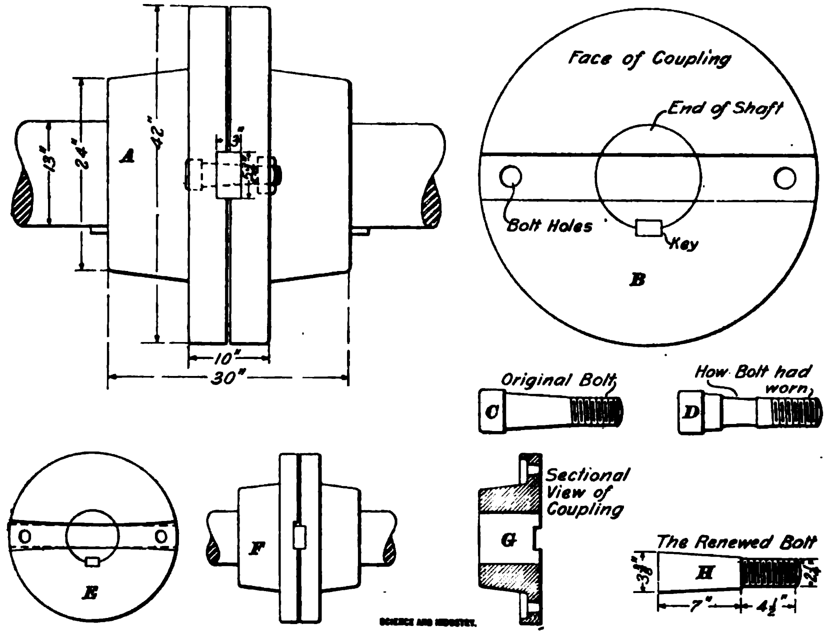


Fig. 1

fed in to clean the entire surfaces of the holes. It was thought best to make a spiral, fluted reamer like that shown in Fig. 2. It was intended to feed this and operate it with a large ratchet and the shank of the reamer was designed with this end in view. After the drawing had been sent to the machine shop, it was found that there was no ratchet large enough to do the work, that would receive a tapered square shank as required by the drawing. The reamer was therefore made with a round tapered shank with a flat end, such as twist drills have, and fitted into a corresponding tapered ratchet of large size which happened to be at hand.

It was found by measurements that the same coupling bolts could be used again by simply turning off the heads and truing the bodies up, and then cutting the thread further up on the bolts to an amount equal to the distance the finished bolts would be fitted into the newly reamed holes. The ends could be cut off the same amount, so as to maintain the original length, which admitted the use of two nuts, one being a thin jamb for security. Fig. 1 *H* shows the finished bolt.

The taper of the holes was 1½ inches to the foot, and of course the reamer was to be the same. In order to clean the holes the reamer had to be fed in just 1 inch, this amount of advance taking ⅛ inch out of the

holes. It may seem, to some of the readers, to have been quite an easy job to do this, but when it is considered that the reamer had work on the

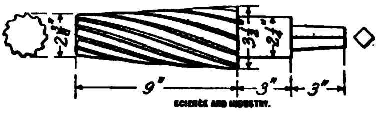


FIG. 2

wrought-iron cross-key as well as on the cast-iron coupling, it should be seen that it could not be done quickly by hand. Besides the nature of the metal to be operated upon, no less important was the extent of the surface. It required quite a force to turn out a cut.

Upon receiving the reamer and ratchet from the shop the job was commenced. The first thing to do was to take out the bolts, which almost fell out after the nuts were removed; the key was next removed, thus allowing each part of the shaft to lie as it would. By calipering the couplings at four points, top, bottom, and sides, and also applying a straightedge to the rim of the couplings, in a direction parallel with the shaft, it was soon found which way the shaft was out of line, and how much.

It was found to be out in the horizontal plane by almost $\frac{1}{8}$ of an inch. It was level the entire length; so that by adjusting the two bearings—one on each side of the coupling—according to the indications of the calipers and the straightedge, the shaft was soon again in line. The cross-key was again shoved in place (it being remembered that it fitted in the right-hand coupling neatly, while it was loose to the extent of about $\frac{1}{8}$ inch in the other), and the openings in the left coupling gauged.

It required just $\frac{1}{16}$ inch on each side of the key (at both ends) to snugly fill the hole, or rather opening, when the couplings were in their relative positions to ream the holes. Having learned this, the key was again withdrawn and dealt with as follows: Four pieces of $\frac{1}{16}$-inch sheet steel 8 inches long by $1\frac{3}{8}$ inches wide, were prepared, and three holes drilled in each to receive $\frac{1}{4}$-inch rivets. The holes were drilled simply by using the point of a countersink drill, because of the thinness of the strips, the rivet heads having to be filed flush with the strips when finished. The strips were then laid on the part of the key to which they were to be secured, Fig. 3, and the holes transferred, the strips being numbered for their respective places. The key was then drilled with a $\frac{1}{4}$-inch tapping drill ($\frac{3}{16}''$) to a depth of 1 inch, and then tapped.

The rivets were made from a $\frac{1}{4}$-inch rod of machinery steel, threaded at the end, screwed in, and cut off to a length, to allow a little more than would exactly fill the hole in the strips when riveted over. The strips were then riveted on and smoothed up with a file.

The key was then entered into its place in the coupling, but could not be coaxed or driven past the center of the shaft. It was thought a little easing off at the point would permit it to be driven home, and after filing one-half of the thickness of one of the strips without gaining much headway, it was decided to rip off that piece entirely, which just allowed the key to be driven home past the narrow part of the keyway. When the key was in place it was open $\frac{1}{16}$-inch

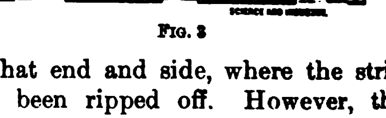


FIG. 3

at that end and side, where the strip had been ripped off. However, the remaining strip at this end of the key received the thrust (owing to the direc-

tion in which the engine turned) so that it mattered little whether the other strip was on or not. Under the conditions, however, there was no chance to pick and choose. At the other end the key was a driving fit. The calipers and straightedge were again applied to the coupling to see if driving the key had altered the position of the coupling. It had not, and the reamer was then introduced. Before commencing to ream, the couplings were clamped tightly against the sides of the key. It should be remembered that the couplings themselves stood apart by ¼-inch, the key and bolts forming the sole connections between the shafts.

It was soon learned that the ratchet was not suitable for the work, when limit of time in which to do it was considered. Anxiety to finish the job made the operators somewhat reckless, and in one of the "spell offs" the fresh man forgot his strength and snap went the shank end of the reamer; the flat end which fits up into the ratchet, and by which the reamer is turned, had twisted off.

A 24-inch stilson was next brought into play to turn the reamer, but as the extent of the cut was becoming greater all the while it was feared that the shank would be twisted off next. But just at the finishing up of the first hole, instead of the shank breaking, the jaw of the stilson parted.

There was not sufficient time in which to finish the remaining hole with the tools as they were, so a bolt was turned up and fitted to the finished hole; the other bolt was placed back just as it had been taken out, the nuts put on and set tightly up, after which the clamps were taken off. The job was thus abandoned until the reamer could be repaired.

How the reamer was repaired can be seen by referring to Fig. 4. It was annealed, and the shank cut off. It was then chucked in the lathe and bored out 2 inches in diameter and 3 inches deep, and a thread cut, eight to the inch. A piece of machinery steel was turned up and threaded to fit the hole quite tight; both collar and point of the piece "brought up" to their respective places, as shown in the figure. The other end was pointed so that a lever, with a center-punched plate on it, could be brought to bear against it to feed it into the hole to be reamed. One-half of the length of this shank which protruded from the body of the reamer itself, was milled hexagonal in form to admit turning it with a wrench; the balance of the shank was round in section.

With the reamer repaired as just described, the hole was finished in

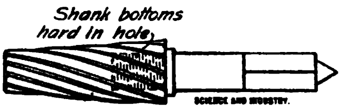


FIG. 4

much less time than was the first one, and the bolt was put in place and tightened up.

As there was a little time remaining, it was thought advisable to withdraw the first finished bolt, and examine both it and the hole in which it was, because the engine had been running during the time between the two attempts to make the repair. While no visible change had taken place, the reamer was run in the hole ⅛ inch further, just as though the entire job had suffered no interruption.

The bolts fitted snugly, and were set up tightly by the nuts, thus securely clamping the sections of the shafting together.

Neither bolts nor key has shown any disposition whatever to again work loose since that repair.

USEFUL FORMULAS—X

JOSEPH E. LEWIS, S. B.

The Beam Formula— $f = \frac{My}{I}$

THE common theory of beams is one of the most useful studies in Applied Mechanics. A full explanation of it would be out of keeping

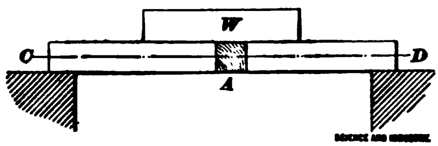


Fig. 1

with the scope and purpose of this article and we will content ourselves with a study of some of its practical applications.

The term f represents what is known as the greatest fiber stress in the beam under consideration, and its value is expressed in pounds per square inch of the cross-section of the beam. In Fig. 1 we have a beam whose cross-section is a rectangle, as shown at A. Upon this beam is placed a weight W, which throws a stress upon it. We have drawn a line, CD, through the center of the beam; the stress above this line is one of compression, and that below the line is one of tension. This line is called the neutral axis of the beam, since it lies in the plane having no stress at all. Now the fibers located farthest away from this neutral plane are subjected to the greatest stress, so that the row of fibers at the very top of the beam are under the strongest compression, and those at the very bottom are under the greatest tension. That is to say, f in the formula represents the stress in that fiber which is located farthest from the neutral axis of the beam.

The location of the neutral axis itself is the next point to settle in order to understand the term y which represents the distance from the neutral axis to the most distant fiber; y is always expressed in inches. Now, it may be demonstrated mathematically, and it has been shown experimentally, that the neutral axis of any beam passes through the center of gravity of its cross-section. In a rectangular section like that in Fig. 1, the center of gravity lies half way between the top and bottom, and therefore the neutral axis cuts the figure in half; that is to say, it passes through its geometrical center. This is true of all symmetrical figures like the rectangle or circle, or any figure of which the top and bottom halves are just alike. In all such sections the center of gravity lies at the geometrical center of the figure, so that the neutral axis divides the figure horizontally into two halves. The sections of the more common styles of beams are symmetrical, so that there is no difficulty in locating the neutral axis. For example, wooden beams are usually rectangular, and steel beams are usually I-beams or channels, or a symmetrical combination of these. In all of them the geometrical center may readily be found, and hence the neutral axis may be located without difficulty. Space prevents our considering here any other

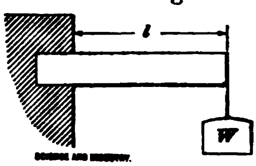


Fig. 2

sections except those which are symmetrical.

Let us pause here for a moment to summarize:

First.—At any section of a loaded beam, if a horizontal line be drawn through the center of gravity of the section, then the fibers lying along this line will be subjected to neither tension nor compression; in other words, the line will be the neutral axis of the section.

Second.—The center of gravity of a symmetrical figure is the same as its geometrical center. Hence, the neutral axis passes through the geometrical center of a symmetrical section.

Third.—The fibers on one side of this line will be subjected to tension, those on the other side being subjected to compression. The tension or compression in any fiber is proportional to its distance from the neutral axis, and the fiber farthest away is subjected to the greatest stress. The intensity of this stress per square inch of section is represented by f, and the distance from the neutral axis to this fiber is called y.

The term M is called the bending moment and is expressed in inch-pounds. The word *moment* in mechanics signifies a force multiplied by a distance. It is much the same thing as leverage. The *bending moment* is the force which produces the bending multiplied by a certain distance which will depend upon the style of beam and the manner of loading.

Fig. 1 represents a beam supported at both ends. Fig. 2 represents one fixed at one end and loaded at the other. This is called a cantilever. These are the two most common kinds of beams, and the only two which we will discuss. Let W be the total load in every case, whether it acts at a single point or is distributed over the full length of the beam, and let l equal the length of the beam in inches.

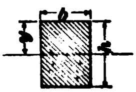
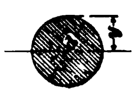
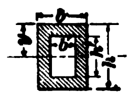
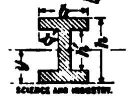
First.—In the cantilever, when there is a single load W at the free end as in Fig. 1, $M = Wl$.

Second.—In the cantilever, when there is a load W uniformly distributed over its whole length, $M = \frac{Wl}{2}$.

Third.—In the case of a beam supported at both ends, when there is a single load W at the middle, $M = \frac{Wl}{4}$.

Fourth.—In the case of a beam supported at both ends, when there is a load W distributed uniformly over its whole length, $M = \frac{Wl}{8}$.

Therefore, knowing the load and the length of the beam, we shall be able to

Section	I	y
	$\frac{bh^3}{12}$	$\frac{n}{2}$
	$\frac{\pi d^4}{64} = .049\,d^4$	$\frac{d}{2}$
	$\frac{bh^3 - b'h'^3}{12}$	$\frac{h}{2}$
	$.049(d^4 - d'^4)$	$\frac{d}{2}$
	$\frac{bh^3 - 2b'h'^3}{12}$	$\frac{h}{2}$

VALUES OF I (MOMENT OF INERTIA) AND y FOR USEFUL SECTIONS

compute the value of M in the formula for each of the four cases above described.

The remaining term I is called the *moment of inertia* of the section about its neutral axis. In the accompanying table we have given a few of the more common symmetrical sections with the moment of inertia of each. We have also indicated the distance y. M will depend upon the style of beam and the manner of loading as explained above.

It will be well to have in mind some average values for the breaking strength of different materials both in tension and compression. We therefore append a brief table. When f as computed by the formula equals or exceeds any one of these values for a given material, the beam under consideration is strained to the breaking point. In practice f should never exceed a certain fractional part of the breaking strength. That is to say, the values given in the table below must be divided by a factor of safety which varies from 3 to 6, or even more, according to the nature of the load. For example, a quiet load may be carried with a smaller factor of safety than a moving load. The value of the factor of safety should also depend upon the reliability of the material used. Thus, steel may in general be used with a smaller factor than cast iron.

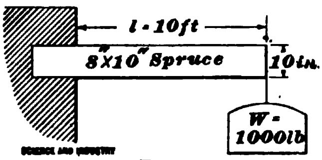


FIG. 3

BREAKING STRENGTH IN POUNDS PER SQUARE INCH OF SECTION

Material	Tension	Compression
Mild steel	65,000	60,000
Wrought iron	45,000	45,000
Cast iron	16,000	95,000
Copper	21,000	50,000
Spruce	6,000	6,000

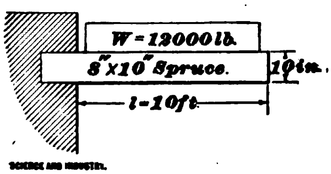


FIG. 4

Below are given the solutions of a few problems:

PROBLEM I.—In Fig. 3 find the greatest fiber stress in the beam.

SOLUTION.— $f=\frac{My}{I}$.

Now, $M = Wl$ in this case as already explained. Therefore, $M = 1,000 \times 10 \times 12 = 120,000$ in. lb., since l must be expressed in inches.

$$y=\frac{h}{2}=\frac{10}{2}=5,$$

and $I=\frac{b\,h^3}{12}=\frac{8\times 10\times 10\times 10}{12}$

$$= 666.66.$$

Then,

$$f=\frac{120,000\times 5}{666.66}=900 \text{ lb.}$$

which shows that the beam is loaded to the safe limit, if not beyond, although it would probably take a load of from 4,000 to 6,000 pounds to break it.

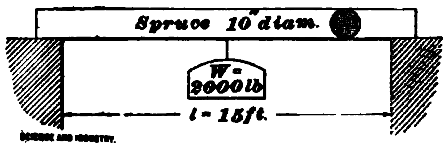


FIG. 5

PROBLEM II.—Find the greatest fiber stress in Fig. 4.

SOLUTION.—In this case

$$M=\frac{Wl}{2}=\frac{12,000\times 10\times 12}{2}$$

$$= 720,000;$$

$y = 5$, as before;

$$I=\frac{b\,h^3}{12}=\frac{8\times 10\times 10\times 10}{12}$$

$$= 666.66;$$

$$f=\frac{My}{I}=\frac{720,000\times 5}{666.66}=5,400 \text{ lb.}$$

which shows that the beam is strained very nearly or quite to the breaking point. A safe load would be about 2,500 pounds instead of 12,000.

PROBLEM III.—Find the fiber stress in Fig. 5.

SOLUTION.—

$$M=\frac{Wl}{4}=\frac{2,000\times 15\times 12}{4}=90,000;$$

$$y=\frac{d}{2}=5;$$

$$I = \frac{\pi d^4}{64} = \frac{\pi \times 10 \times 10 \times 10 \times 10}{64} = 490.87;$$

$$f = \frac{My}{I} = \frac{90{,}000 \times 5}{490.87} = 917 \text{ lb.}$$

which shows that the 2,000-pound weight is a safe load for the beam in question.

PROBLEM IV.—Find the fiber stress in Fig. 6 for a cast-iron beam circular in section and hollow; outside diameter equals 12 inches, inside diameter equals 8 inches.

SOLUTION.—

$$M = \frac{Wl}{8} = \frac{3{,}000 \times 12' \times 12}{8} = 54{,}000;$$

$$y = \frac{12}{2} = 6;$$

$$\begin{aligned} I &= 0.049\,(d^4 - d'^4) \\ &= 0.094\,(12^4 - 8^4) \\ &= 0.049\,(20{,}736 - 4{,}096) \\ &= 0.049 \times 16{,}640 = 815, \text{ approx.} \end{aligned}$$

$$f = \frac{My}{I} = \frac{54{,}000 \times 6}{815} = 400, \text{ nearly,}$$

which shows that the beam is carrying only about one-eight or one-tenth of its maximum safe load.

Now, the result in each of the above problems is too small by reason of the fact that we have not taken into account the weight of the beam itself. The values of f, which we have found, must therefore be corrected in order to represent the actual fiber stress. Take Problem I, for example. Spruce weighs 25 pounds per cubic foot; then the beam weighs 138 pounds, which is a distributed load. Then the fiber

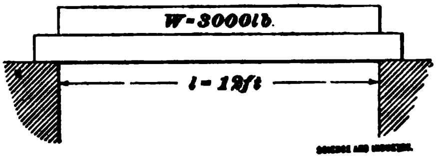


FIG. 6

stress, due to the weight of the beam itself, will be computed as follows:

$$M = \frac{Wl}{2} = \frac{138 \times 10 \times 12}{2} = 8{,}280;$$

$$y = 5,$$

$$I = \frac{bh^3}{12} = \frac{8 \times 10 \times 10 \times 10}{12} = 666.66;$$

$$f = \frac{My}{I} = \frac{8{,}280 \times 5}{666.66} = 62.1 \text{ lb.}$$

Adding this to 900 pounds gives a total fiber stress of 962 pounds.

The values of f in the other three problems should be corrected in the same way, by considering the weight of the beam as a distributed load which it carries.

THE CHICAGO & ALTON'S EMPLOYMENT BUREAU

The Chicago & Alton Railway has established an Employment Bureau, the purpose of which is to recruit employes from among the people living along the line of the Alton road. The head of the "Alton" Employment Bureau meets citizens living in towns upon and adjacent to the line of the Alton Railway for the purpose of getting in touch with young men of good habits and high character who would like to become employes.

Students in telegraph offices, clerks in various departments, operators, brakemen, firemen, etc., are recruited from persons whose record is kept by the Alton's Employment Bureau, the selections being made from those who are best suited and qualified after having passed mental and physical examinations which have been made a part of the requirements for employment by the Chicago & Alton Railway Co.

SOME POINTS ABOUT CONNECTING UP SHUNT MOTORS

THERE is nothing complicated about the connections for a shunt-wound motor, and yet it is surprising the number of times these motors are incorrectly connected. Although the connections are simple, it is a matter of fact that wrongly connected shunt motors have in some cases given rise to a great deal of trouble and annoyance, to say nothing of damage to the motors themselves.

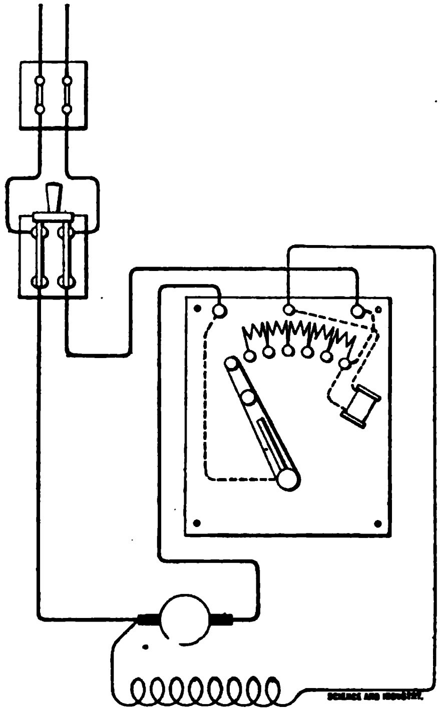


FIG. 1

In the first place these motors are nearly always operated from constant-potential mains, and it is necessary to insert a resistance in series with the armature at starting. This is done to prevent the heavy rush of current that would otherwise occur on account of the counter E. M. F. being zero when the armature is at a standstill. As the motor comes up to speed, the starting resistance is gradually cut out until, when full speed is attained, the armature is directly across the line. The starting resistance is, therefore, connected in series with the armature.

Figs. 1 and 2 show two correct methods of connecting up a shunt motor with its starting rheostat. In both cases the rheostat is provided with a release magnet in series with the shunt field. This holds the arm at the "on" position against the action of a spring, so that if the power is shut off for any reason the lever at once flies back to the "off" position, and thus insures that the motor shall not be started up with the resistance out of circuit. Both methods shown in Figs. 1 and 2 are in use for shunt motors. The same connections are shown in Figs. 3 and 4 in diagrammatic form so that the difference between the two may be readily seen. In Fig. 3, which corresponds to Fig. 1, the field is connected so that it is excited from the mains as soon as the main switch is closed, and before the rheostat is moved to the "on" position. In Fig. 4, which corresponds to Fig. 2, the field is not excited until the arm is moved to the first point on the rheostat. The advantage of this latter method is that the field circuit of the motor is not opened when the rheostat arm flies back to the "off" position on account of the power being shut off. There is, therefore, little or no sparking at the last contact, and the field is relieved of the strain caused by the induced E. M. F. set up when the field circuit is suddenly opened. It is true that the field current has to pass through the starting resistance, but the current is so small and the starting resistance so low compared with that of the shunt field that this makes little or no difference. Sometimes an additional connection is pro-

vided, as shown by the dotted lines, Fig. 4, so that the field current will pass through the resistance only during the interval of starting.

It is claimed in favor of the scheme of connections shown in Figs. 1 and 3 that the closing of the field circuit before current is allowed to flow through the armature allows the field time to become magnetized, and thus give a better starting effort than the plan shown in Figs. 2 and 4. How-

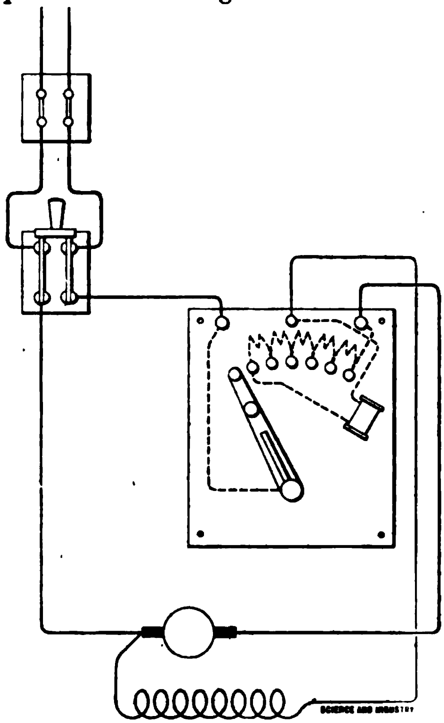


FIG. 2

ever, the field magnetizes so quickly that this objection carries little weight. If the rheostat arm is allowed to rest for a few seconds on the first point, the full starting torque is obtained.

The most common m'stake made in connecting up shunt motors is that shown in Figs. 5 and 6. These same connections are shown diagrammatically in Figs. 7 and 8. The mistake is in confusing the two heavy wires and the result, as indicated in Figs. 7 and 8, is to practically connect the shunt field directly across the

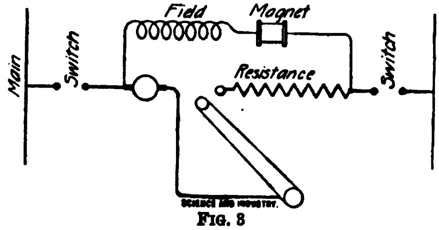


FIG. 3

brushes. The pressure applied to the field will, therefore, be always equal to the pressure across the brushes. Now, suppose that the armature is standing still and that the rheostat is moved to the first point. The motor does not start because the pressure between the field terminals is too small to provide sufficient field excitation. The resistance of the armature is very low, and the pressure between its terminals, so long as the motor is not running, is equal to the current multiplied by the resistance of the armature. As the rheostat arm is moved still farther, the current increases, and the pressure across the brushes also increases, but it is still too small to cause much field excitation. The large part of the pressure is taken up in forcing the current through the starting box. As the lever is moved over still farther, the chances are the box will begin to smoke and the armature may also be overheated. If the load on the motor is very light, it may start up after the lever has been

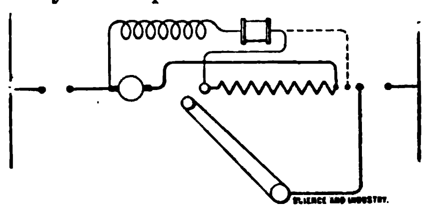


FIG. 4

moved a considerable distance, because a weak field may set up sufficient starting effort. When it does start, it

will run up to speed with a rush, because, just as soon as the armature begins to turn, it generates a counter E. M. F. with the result that the pressure across the brushes and consequent field excitation rises very rapidly. If, however, the load is at all heavy, the motor will not start, and unless the starting lever is moved back promptly to the "off" position, there will be danger of burning out both box and armature. Whenever a motor behaves as described, the connections should be examined very carefully. The chances are that they have been confused so that the field is either connected across the armature as above, or else there may be a break somewhere in the field circuit. If the latter is suspected, the field circuit should be carefully examined and tested with lamps or a magneto.

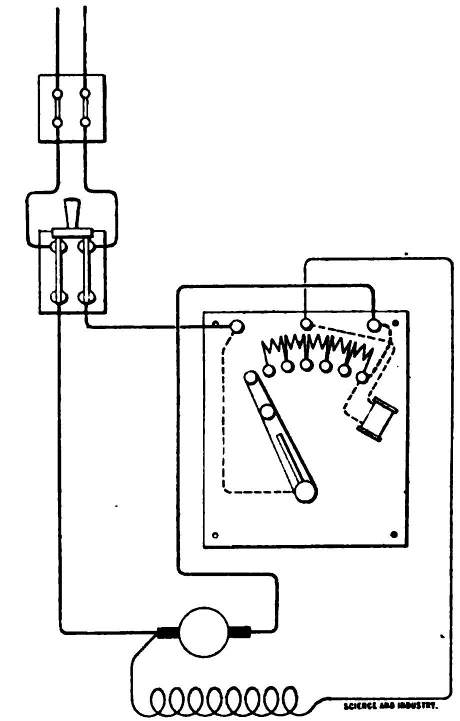


FIG. 5

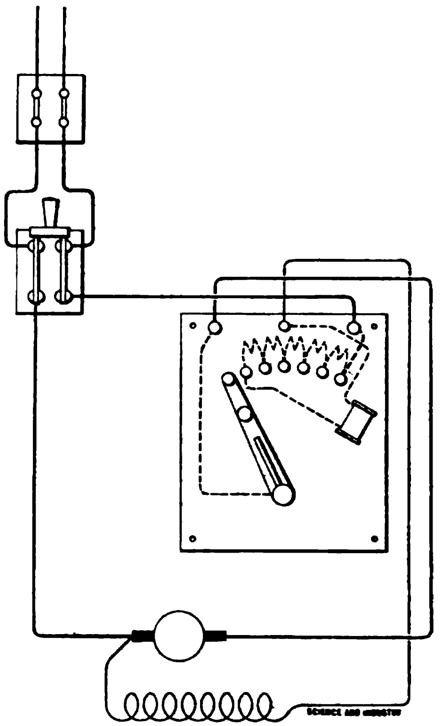


FIG. 6

These connections are so simple to follow on a diagram that it would seem as if there should be little trouble in getting them right. In a given motor installation, however, it must be remembered that the wires are often run together in conduit, or the motor may be at one point and the starting box at another. Under such circumstances the connections are easily confused. The writer has in mind one case where a 220-volt, 1-horsepower motor was used to pump a church organ. The normal full-load current of this motor was about 4 amperes. The motor was controlled by means of a rheostat, the arm of which was operated by the movement of the bellows. It was noticed that the motor did not start up until most of this resistance was cut out, and that when it did so it was with a howl and a rush

that was sometimes plainly heard in the church, although the motor was situated up in the tower above the organ. The motor was also continually blowing fuses and blackening its commutator. The machine ran in this way for over six months and kept the organist so busy putting in fuses that it was decided to investigate. An ammeter was placed in circuit and it was found that 50 amperes were required for starting, which, of course, was out of all reason. The connections were then carefully traced out, and it was found that the shunt field was connected across the armature, but as the apparatus was arranged on two floors this point had not been noticed when the motor was installed. The connections were rectified and the motor gave no further trouble. A test showed that it now started on 2 amperes.

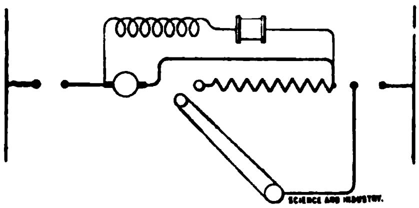


FIG. 7

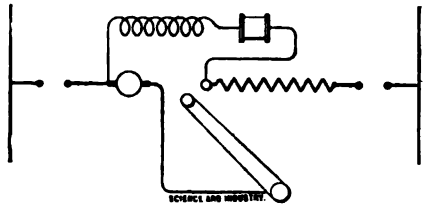


FIG. 8

A SINGLE-PHASE ELECTRIC RAILWAY

SO FAR no trolley roads have been operated on a commercial scale in America by means of alternating current. In many cases the power has been transmitted by means of alternating current at high pressure, but it has always been changed to direct current for operating the cars. The principal reason for this has been the difficulty of producing a satisfactory variable speed alternating-current motor that would be in all respects the equal of the direct-current motor. Trolley cars have been operated to a limited extent in Europe by means of three-phase motors, but one objection to such motors is that they necessitate at least two trolley wires, thus complicating the overhead construction.

The announcement is now made that a contract has been closed for a road between Washington, Annapolis, and Baltimore, and that this road is to be operated by single-phase alternating-current motors. The road is to be installed by The Westinghouse Electric and Mfg. Co., and the system to be used is one developed by Mr. B. G. Lamme. Heretofore the single-phase motor has not been considered at all adapted to traction work, being much inferior to the polyphase motor. It is claimed, however, that in the system to be adopted that the objections to it have been overcome. Of course, with the single-phase system there is the great advantage that only one trolley wire is required, thus placing it on a par with the direct-current system so far as overhead work is concerned. With alternating current on the cars a higher pressure can be used at the motors, all rotary converter substations are done away with, and the cost of operation is thereby materially reduced.

The total length of the road in question is 40 miles from Washington to Baltimore, with a 15-mile branch to Annapolis. The fact that such an important road is to be so equipped shows that the promoters have great faith in this system.

THE ECONOMY OF MECHANICAL STOKING

R. T. STROHM

THE whole secret of the marvelous success which has attended the use of most mechanical devices for stoking lies in the fact that they give conditions which at least approximate, if not very closely approach, the conditions necessary for the economic and complete combustion of coal. It cannot be denied that in competitive tests, results by hand firing were obtained which quite equaled the results secured by the use of the mechanical stoker. But in those tests the firemen were well trained, intelligent and efficient, which in itself is a condition none too frequently met in a large number of steam plants. And for this reason it may be safely stated that the mechanical stoker in general shows better results than the average hand firing.

Complete, and therefore economic, combustion of coal depends upon a sufficient air supply admitted in such a way as to be thoroughly mingled with the hot gases while they are at or above their igniting temperature. In the ordinary furnace this air is supplied through the interstices in the grate, from the ash-pit, after which it mixes with the volatile matter driven off from the fuel by the heat. So long as sufficient air meets carbon particles which are still red hot in the flame, and hence at a combining temperature, no smoke will be formed.

To obtain an unrestricted air supply, it is necessary to keep the air spaces in the grate free from ashes or clinker. It is quite as necessary to keep the fire clean also, since the air could not well pass through a fire which was underlaid with a layer of ashes and clinker.

With hand firing it is not always an easy matter to keep the fire clean and the grates and ash-pit free from accumulations of refuse. The fireman's duties usually entail something besides shoveling coal into the furnace and removing ashes. He cannot always be cleaning the fires.

On the other hand, the mechanical stoker by its arrangement and operation obviates these very deficiencies. The sections of which the grate is composed have a slight motion compared with each other, or else they are arranged so as to move in unison with a reciprocating motion, the result being that the clinker is loosed from the bars and broken up, and the finer ashes sifted through the grates into the ash-pit. As a consequence, the fire is kept clean more continuously than would be possible with hand firing. Of course, it is necessary at times to clean the fires when a mechanical stoker is used, for refuse may clog the air spaces of the grates so persistently that even the motion of the bars cannot shake it loose. Especially is this the case with a fuel which contains fusible impurities. This foreign matter will form into a slag under the action of the heat and will adhere most tenaciously to the grate, so that nothing short of the use of the slice bar and the poker will effectually dislodge it.

One of the primary conditions for smokeless and economical combustion is frequent firing in light charges, so as to maintain as thin a fire as possible. The reason for this should be apparent. A thin fire will offer much less resistance to the passage of the air through it than will a thick one, and so the thin fire has the advantage of the better air circulation, and hence the greater opportunity for the complete chemical union of the

combustible elements with the oxygen. Further than this, the furnace ought not to undergo any considerable changes in temperature. That is, the heat should be kept of an intensity as nearly uniform as possible. Now, this would be an impossible condition if heavy charges of fresh fuel were fired at long intervals. For if the brightly burning, incandescent bed of fuel were to be covered with a thick layer of fresh coal, all radiant heat from the hot coals would be cut off, and the fire for a time would be practically deadened. It would require some little time before the fresh coal would become thoroughly ignited, during which period the furnace temperature would fall considerably. This would not be the case, to so great an extent, if the amount of fuel fired were small. For then it would take but a short time to ignite the fresh coal, and in such a short period the walls of the furnace would not cool down so considerably.

In connection with this there comes the question of admitting cold air through the fire-doors when they are opened for firing. If the doors were open a long time, as would be the case with the firing of large charges, the cooling effect of the air would be considerable. This would not be so evident in the case of light, frequent firing. For then, while the doors would be open oftener, the inrush of cool air would be confined to shorter periods and so give the walls and plates the opportunity to recover the more quickly from their chilling.

In a very great number of plants the style of fuel is bituminous coal, and this type contains quite a large percentage of volatile hydrocarbons, or compounds of hydrogen and carbon, which may be driven off as gases under the continued application of heat. This process is known as distillation, resulting in the production of coal gas and coke, and it takes place, to a certain extent, in the furnace of every boiler using bituminous coal as a fuel. To obtain the best results, however, where bituminous grades are used entirely, the coking system of firing must be used. This system consists in placing the fresh fuel in the coolest part of the furnace at first, allowing it to remain there until the heat has driven off most, or quite all, of the volatile matter, leaving a solid residue consisting of good coke. This is then broken up and pushed back on the grate, where it burns quickly, with great heat and without smoke.

Acknowledging, as we must, that the coking system is the best for soft coals, we have a strong argument in favor of the mechanical stoker for burning this fuel. All mechanical stokers are operated on one basic principle; that is, they feed the coal at one point in the furnace, commonly the front, where it is allowed to accumulate until well coked, after which the solid residue is carried back upon the grate either by an oscillatory movement of the grate bars, or by the continuous travel of the whole grate surface toward the bridge wall.

During the coking process, the gases that are driven off are highly inflammable, and in passing to the chimney they must go over the bed of burning coal, with the result that they are quickly ignited. Sufficient air is then admitted, either through the fuel bed or at the bridge wall, and these gases are completely burned without the formation of smoke, which is certainly a most desirable attainment in the use of a coal which contains so generous an amount of smoke-making elements.

The duties of a fireman are usually sufficient to keep him fairly busy. He

must look to the condition of his fires, the cleaning of grates and ash-pit, the maintenance of the proper water level, and in many cases the haulage of the coal from a nearby storage bin. Now, no matter how careful he is, it is impossible for him to fire with clock-like regularity. In many instances the firing must be done along with the performance of other duties of an urgent nature, and the result is irregular firing. Consequently, the fire is thick or thin according as the period between firings has been short or long. The fire may even have had time to burn out in spots if it has been neglected for a longer period than usual. This is not economical, and certainly not efficient, yet at times it is almost unavoidable with hand firing.

The mechanical stoker, on the contrary, is always regular in its action, since it is operated by a continuous positive motion. The amount of coal fed can of course be regulated according to the demands for steam, by causing the stoker to operate more rapidly or the coal-feeding attachment to furnish greater quantities of fuel. But in any event the thickness of the fire is nearly uniform over the surface of the grate, and the firing continuous, maintaining an approximately constant degree of temperature in the furnace.

When the amount of coal burned per day by the plant is small, a mechanical stoker will scarcely show an increased economy of operation, since the fireman can readily attend to the firing, and he is a necessary part of the equipment, whether a stoker is used or not. But where several batteries of boilers are in operation in one plant there can be no gainsaying the fact that not only is the amount and cost of manual labor reduced, but there is an actual saving in fuel by the use of the mechanical stoker.

PRINCIPLES OF ELECTRICAL MEASURING INSTRUMENTS

In most measuring instruments used in electrical work, the action of the moving parts is brought about by the interaction of the magnetic lines

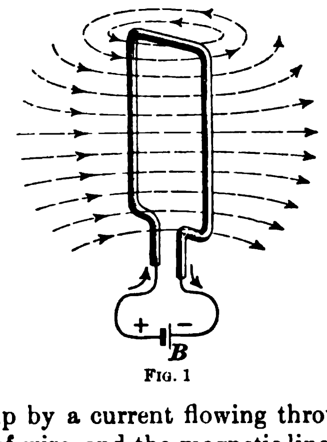


Fig. 1

set up by a current flowing through a coil of wire, and the magnetic lines of a permanent magnet, or of another movable coil. When a current flows through a wire, magnetic lines are set up around the wire. The lines form concentric circular paths with the wire at the center. If a small compass needle be placed near a vertical wire that is carrying a large current, the north pole of the needle will point in a certain direction. If the current in the wire is reversed in direction, the north pole of the compass needle will point in the opposite direction. We can consider that the direction of the lines of force around the wire is the same as the direction in which the north pole of the needle points as it is carried around the wire. If we are looking along a length of wire, and the current is flowing away from us, the direction of the lines of force will be in the direction of the movements of the hands of a clock.

If the current is coming toward us the direction of the lines will be opposite in direction to the movement of the hands of a clock.

Instead of a straight conductor, take a wire and form it into one complete turn, as shown in Fig. 1. Magnetic whirls will be set up around the wire when a current flows. The lines thread through the coil from the side toward us to the side away from us. If we reverse the current flow, the lines are set up in the opposite direction.

The general distribution and direction of the lines of force of a permanent magnet are indicated by Fig. 2. The lines emanate from the north pole N of the magnet, pass through the air, and enter the south pole S, then passing through the magnet to the N pole. When a magnet is placed in a magnetic field, the magnet, if free to turn, will tend to so place itself that the lines of force of the field, in which it is, will coincide in direction with the direction of the inside magnetic lines of the magnet. If a bar magnet is suspended by a string in the earth's magnetic field, it will point in such a direction that the earth's lines will enter its south pole and pass through the magnet to its north pole.

Suppose that the turn of wire shown in Fig. 1 is so placed that the sides of the coil face east and west and the plane of the coil is in a north and south position. Now suspend a small magnet at the center of the coil. The magnet will point north and south as long as no current flows. Now, allow current to flow so as to set up the lines of force in the direction indicated in Fig. 1. The direction of these lines is at right angles to the plane of the coil. The magnet now has two forces acting on it: the earth's field tends to keep

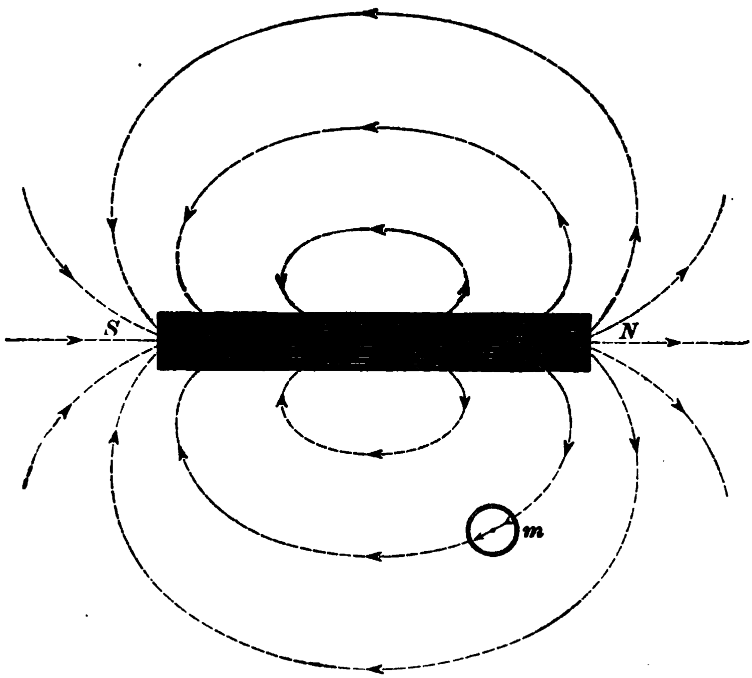


FIG. 2

the needle north and south and the coil field tends to cause the needle to point east and west. The needle

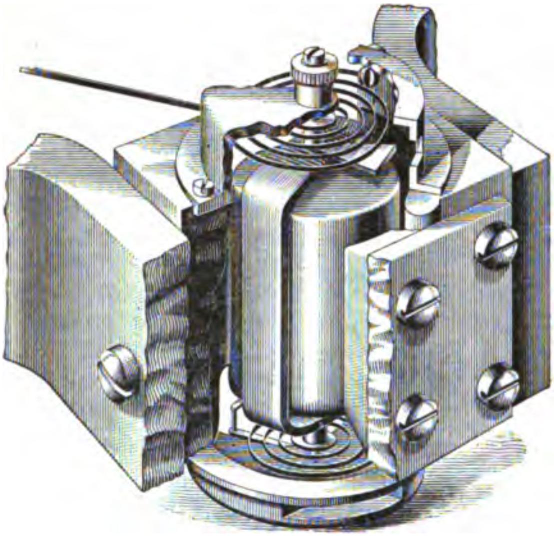


FIG. 3

tends to set itself so that the coil field lines will enter its south pole and emanate from its north pole. The needle will be prevented from turning at right angles, unless the coil field is much more powerful that the earth field. The needle is usually deflected to some intermediate position between its 0° position and its 90° position. The readings on the degree scale of the instrument, over which a pointing needle, connected to the magnetic needle, passes, does not give the value of the current directly, but the value may be calculated from the deflections and known data. Instead of a single turn of wire, a coil consisting of a large number of turns is used in the galvanometer. Deflections in either one direction or the other may be obtained by reversing the direction of current in the coil.

In place of a movable bar magnet a coil of fine wire may be suspended between the poles of a permanent magnet. The current is led to and from the coil by means of small springs. The springs keep the coil in such a position that the pointer is at zero on the scale when no current is flowing. When current flows through the coil it is deflected and tends to turn against the springs so that the lines of force set up through the coil, by the current flowing through the coil, will coincide in direction with the lines of force from the north pole piece of the magnet to the south pole piece. Fig. 3 represents part of a Weston instrument.

The scale is usually arranged so that amperes in the case of an ammeter, or volts in the case of a voltmeter, may be read directly from the scale.

In a wattmeter the small

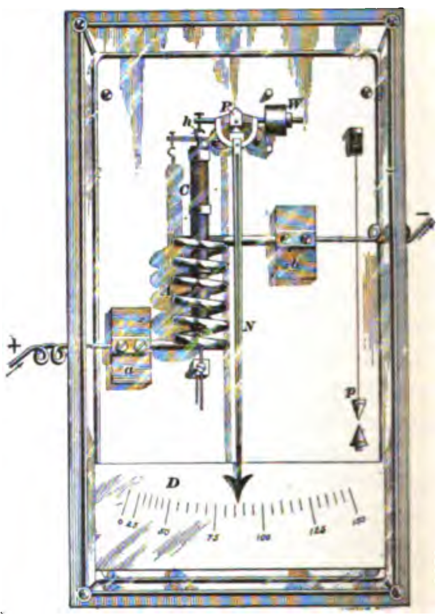


FIG. 4

movable coil in series with a high resistance is connected across the line and two large coils wound with large

wire and connected in series with the device to be measured, furnish the field lines of force in which the movable coil turns. In such an instrument there is no permanent magnet or iron in the coils. The wattmeter can be used for either direct or alternating current.

When an iron core is suspended by a spring or weight over a coil of wire and current allowed to flow through the coil, the core is drawn into the coil. Ammeters and voltmeters made on this principle have been used to measure current or E. M. F. The core will tend to so set itself that it will carry as many lines of force as possible. The spring or weight acts against the magnetic pull and limits the readings. Fig. 4 shows a plunger type of ammeter.

The current enters at a and passes through the solenoid A to b. The weight of the core C is balanced by the counterweight W, so that the needle N points to zero on the dial D, when no current is flowing.

There are several other instruments, the action of which is based on the fact that if a movable piece of iron is placed in a magnetic field, the piece of iron will turn or move so as to offer passage through it to as many lines of force as possible, iron being much more permeable to magnetic lines than air. These pieces of iron are connected to needles that indicate values on the instrument scale.

MEASURING HIGH RESISTANCES BY WHEATSTONE BRIDGE

IN ELECTRIC light and power stations it is sometimes desirable to determine by means of a Wheatstone bridge the value of an unknown resistance that is too high to be measured with the bridge in the ordinary direct manner. Provided there can be conveniently obtained a lower resistance, such as a number of series-connected incandescent lamps or a high-resistance field rheostat, whose resistance can be directly measured by the Wheatstone bridge, the value of the unknown high resistance can be determined in the following manner:

First measure the lower resistance and suppose that it is equal to y ohms. Then connect this resistance, having y ohms in parallel, or multiple, with the high unknown resistance; measure the joint resistance of the two joined in parallel and call the result obtained z ohms. Then, if x is the unknown high resistance, we have

$$z = \frac{xy}{x+y},$$

from which we get

$$x = \frac{yz}{y-z}.$$

Where x is not very much higher than the largest resistance that can be accurately measured in the ordinary direct manner, y should be as high as can be accurately measured by the bridge, at least several thousand ohms. When y is accurately measured or known and x is not too high this is a very good method. It is evident that this method may be used in order to determine whether resistances that have been measured separately are correct within reasonable limits.

The following example will serve to illustrate this way of measuring an unknown high resistance. Let the resistance y, measured by itself, be 60,201 ohms and let the result z obtained by measuring y and the unknown in parallel, be 57,010 ohms; then the unknown resistance

$$x = \frac{60{,}201 \times 57{,}010}{60{,}201 - 57{,}010} = 1{,}075{,}600 \text{ ohms.}$$

AGRICULTURAL POWER MACHINES

GEORGE E. WALSH

AMERICAN agricultural machinery operated by steam and electricity has in the past half dozen years revolutionized farming conditions in the West to such an extent that the engineer has become almost as important a factor in agriculture as the farmer. The machinery thus invented and practically employed upon thousands of mammoth grain farms of the West has called into existence a new type of engineer, whose duty it is to know something of the mechanical manipulation of rather complicated machinery along with a general knowledge of agriculture. The modern agricultural colleges are turning out students of farming who are practical soil chemists and scientists, but few of these institutions have kept sufficiently abreast of the times to educate them, at the same time, in mechanical engineering. Consequently the call upon the technical schools for competent agricultural engineers has been unusually large, and the supply is yet hardly equal to the demand.

American farm machinery has always stood in the front rank of any similar inventions in the world. It was the first McCormick reaper which called forth from the British statesman the remark that it created agricultural possibilities which would redound to the benefit of mankind more than any other invention of the age. This prophecy proved so true that within half a century the crops of the world were doubled and tripled, largely through the instrumentality of the new machine for gathering and harvesting them. Within the past quarter of a century American inventors have turned their attention to farm machinery, so that today our agricultural output is the largest in the world. We manufacture and export to all parts of the world farm machinery to the value of several millions of dollars. It is our improved farming implements which enable our agriculturists to raise wheat and corn a thousand miles from the seaboard, and ship it half way around the globe, and successfully meet in competition the cheap-labor produced grains of the Argentine Republic, where wheat fields yield enormous crops within sight of the ocean steamers waiting to carry them to Europe.

But an entirely new phase of our farm machinery was inaugurated a few years ago when steam power was first substituted for the horse, and this new era of farming by means of steam and electric power promises to make our agricultural possibilities far greater than ever before. Beginning with small steam traction engines to drag plows and cultivators across the fields, the inventors have gradually constructed mammoth steam plants on farms of tens of thousands of acres in extent. Following quickly in the footsteps in the mammoth traction engines came the portable threshing outfit, the giant steam harvesters, binders, and cultivators, and machines to shell and grind corn, to stack hay and straw, and to carry the grain into private elevators on the farms. That we are still on the threshold of this new phase of farming is apparent from the changes and improvements made nearly every season.

The modern farm traction engine is designed to burn coal, wood, oil, or straw. The fuel problem has always been a perplexing one in the central prairie states where to import coal is so expensive that farmers for many

years have used corn cobs to heat their homes. A ton of coal in ordinary seasons will sell from $8 to $10 in the isolated farming sections of these great prairie states, and the profits of the year's crops are seriously impaired if one must burn much coal. On the modern mammoth farm, however, coal is used for operating the machinery to a large extent, but oil and straw have proved more popular and less expensive. A good many of the machines are now operated entirely by these fuels. The oil is supplemented by straw whenever a supply of the latter is at hand.

Straw has always proved a nuisance to the farmers in the grain regions, and they formerly burnt it standing in the field, after the tops with the grain were clipped off. The modern harvesters are made to cut the grain and straw together, and as the grain is threshed out the straw is supplied as fuel by an endless-chain device which carries the straw to the fuel box of the engine as fast as it is needed. In this way the accumulating piles of straw are kept down to reasonable proportions, while only a single man is required to regulate the feeding of the engine. This of course is applicable only to the machine used for threshing. At such times it is stationary, and the feeding of such light fuel as straw is practicable.

In recent years the attempt has been made to compress the loose straw into small compact bricks or bales which would make it more suitable for fuel than when loose. The straw has been hydraulically pressed and mixed with a little oil, and while in this condition it has been fed with fair success to the boilers. Specially prepared fireboxes have been made for straw fuel, and their adoption in some localities has proved satisfactory to the operators. Another fuel which has been used to some extent in the corn belt is the cobs of the corn. These cobs when soaked a few minutes in oil produce a vivid and steady blaze of intense heat. The cobs alone make excellent burning material, but when soaked with oil they are very inflammable. Very little draft is required in the furnace to insure a steady heat. The use of cobs for burning, however, is confined almost exclusively to the corn belt, and there the mammoth reapers and threshers are not in use. The large corn shelling machines are run by this fuel, and these machines operated by steam shell 1,000 and more bushels of corn every day. The corn is brought direct from the farm bins to the shellers, and dumped in a huge wooden box or vat, from which it is carried by an endless chain to the sheller. It is fed automatically as fast as the machine can shell it. Three men can operate one of these shellers, and as a result of a day's work they shell from 1,000 to 1,500 bushels of corn. The cost of fuel is very little where cobs are used. While a ton of coal would cost from $8 to $10 per ton, and nearly a ton would be required for a day's operation, the cobs are at hand for the mere cost of handling them. Less than 2 tons of cobs, soaked in oil so that about 50 gallons are absorbed at a cost of $1 a barrel, will run the shellers for one day.

The largest of the modern harvesters operated by steam traction engines have cutting bars 35 feet long, and with such an enormous reach that the work of harvesting grain is greatly simplified and quickened. The harvester of this type is independent of the traction engine which is employed to accompany most of these machines. Its motive power is supplied by an engine of 8½-inch bore and 7-inch stroke, located on the frame of a harvester.

Steam is conducted to this engine by a flexible tube from the big traction engine of 50-horsepower that always accompanies the harvester in its operations. The idea of supplying the harvester with its own auxiliary engine is to secure a more uniform motion in crossing the grain fields. When hauled by the traction engine the harvester always fails to accommodate itself to the condition of the surface over which it is traveling. When halted for threshing purposes, the combined harvester has with it two engines for operating different auxiliary machines. With the two engines supplied with steam from the boiler of the large traction engine, 1,000 to 1,500 sacks of wheat can be cut, harvested, and threshed in a single day. This means that from 70 to 100 acres of grain can be harvested and prepared for market each working day of the week at an average cost of 50 cents per acre.

These combined harvesters cut the grain, thresh it, clean and grade it, and sack it for shipment. The combined mechanism of the machine is of interesting complication. The threshing is actually performed while the machine is crossing the fields, and the straw is deposited in the fields after it. When cut by the enormous cutting bar, the straw is conveyed to the threshing mechanism by means of an endless chain. The threshing cylinder is 28 inches in diameter, and this cylinder operates on the same principle as the smaller threshers that have been in use for years. When the grain has been threshed out it flows down from the series of cylinders with the straw, but almost immediately the two are separated, and a series of fans drive the chaff from the wheat and keep the straw from mixing with the grain again. There is an automatic governor on the fans which regulates the wind so that there can be no clogging of the machine at any point. The wind can be regulated so that wet, heavy straw could easily be blown steadily along. The automatic separator has a total width of 54 inches, and it performs its work so satisfactorily that the wheat is rarely mixed with dirt or chaff when finally thrown out. The straw is conducted to the straw box in the rear, where it is either dumped out on the field or caught up by a different mechanism, to be carried to the firebox of the traction engine and used as fuel. The cleaning and sacking mechanism is very simple, and the sacks of filled wheat are dropped at regular intervals on the field. The bags for the cleaned wheat are put in position by men in a series so that half a dozen are waiting a turn to be filled, thus preventing any delay or loss should any interference happen to the operator's work.

Not much less important and interesting than the modern combined harvester and thresher are the plows and cultivators and seeders operated by steam. In most cases these are simply drawn across the field by powerful traction engines with flanges on the wheels several feet in width. Owing to these wide wheels, the machine can operate in a field right after a rain without sinking into ruts. A great variety of machines for farming can be operated by one such traction engine, but the tendency is to invent individual steam engines for each series of machines so they can be operated separately. By using cheap fuel oil it is hoped that this method of plowing and cultivating will prove successful. A good deal is gained by this method. The machines can be lighter, and they will prove more successful in accommodating their work to different kinds of fields. Very hilly and rolling country

is always more difficult to cultivate with the modern heavy steam traction implements than land which is perfectly level. The steam-operated plows and cultivators have consequently failed to recommend themselves to farming land in many different parts of the country.

The present method is to have the traction engine do a great multiplicity of farm work. Plowing is the most difficult. So far there is plenty of room for improvement in this direction. There are two methods of plowing by steam-operated machinery. One is to have the engine stationed at one side of the field, and a heavy iron pole at the opposite. The plow is then hauled back and forth by means of a cable. The plow is in reality a series of a dozen plows arranged in such a manner that a number of furrows are turned over in each trip across the field. This method is satisfactory only where the field is a large one, and the length of each furrow is of considerable extent, for the work of moving the position of the engine and opposite pole requires considerable time and labor. The other method is to produce a plow which moves with the traction engine in long trips back and forth across the fields. Combined with this is a machine for harrowing and planting the grain. Following the plow in close order comes a harrow which breaks and pulverizes the soil so that it is ready for the seed. An automatic seeder drops the seed or spreads it broadcast behind the harrow, and a roller comes on last to press it firmly into the soil.

Four distinct operations are thus accomplished in each trip across the field. This method is by all odds the most satisfactory, but the machines employed for it are still far from perfect. The planting is not yet as satisfactory as that done by hand or by horse machines. There is lack of mobility about the heavy machinery which makes no allowances for slight undulations in the soil or accidents of a trivial nature. Where crops need to be planted in hills or rows, and covered with an inch or two of soil, the machines are provided with special attachments. Some have small cultivator disks follow the harrow which carve into the mellow seed bed a straight row across the field, and the seed is all dropped uniformly in this row and covered by a small cultivator plow behind. In corn planting in hills, the machinery is adjusted so that every few feet an automatic digger prepares a small hole for the seed, and this is filled up and hilled to the proper height by another ingenious invention.

There is an endless variety of such farming machines which are today operated by steam power, and their annual improvement brings us nearer to the time when most of our crops will be sown, harvested, and marketed without once being handled by anything other than machinery. On the great western potato farms, planters and diggers are employed so that the crop is raised without being touched by hand. The large western hay farms have traction engines to cut the hay and to stack it, and then to load and unload it by derricks operated by the same engine which hauls the reaper. Likewise it is baled and loaded on the cars which back up in the fields. There is, in fact, at nearly every stage of modern farming on a large scale, some steam-operated machinery to simplify and increase the speed of the farmer's work. A study of these conditions is almost necessary for the modern engineer who wishes to keep abreast of the times in all departments of his calling.

PRACTICAL POINTS ON LUBRICATING OILS

WILLIAM K. RICHART

THE selection of the proper lubricant for a journal or bearing depends largely upon the conditions, viz., speed, size of shaft, pressure, temperature, etc. In America, where petroleum is so generally used as a lubricant, the many by-products furnish a varied assortment to draw from. The different oils and greases manufactured in this country are principally composed of petroleum by-products which are obtained during the process of distillation of crude oil. The lighter oils, used principally for engine and dynamo lubrication, are extracted from paraffin wax, and the heavier-bodied oils, such as cylinder stocks, remain in the still after the lighter oils have passed over the worm. The light-bodied oils, which are extracted from the paraffin wax, are called neutral oils, and from these are compounded many of the various lubricating oils of different consistencies. Cylinder stocks form the base of valve and cylinder lubricants. Usually compounders use 80 per cent. of cylinder stock and 20 per cent. of animal oil compounded at 220° F., and thoroughly mixed together. This forms a very satisfactory valve and cylinder lubricant. Cylinder stocks are treated in many different ways. The dark green color is the natural state, and the light red is the result of passing it through the bone-charcoal filter, which produces the oil usually termed as "filtered cylinder oil." The petroleum lubricating oils are usually blended with animal or vegetable oils, and often a lighter product of petroleum is increased in gravity by the addition of heavier oils to make it of a heavier consistency. In order to specify the oil required for any special purpose, an engineer should know about what degree of cohesive property or viscosity the oil contains. The modern methods of applying lubricating oil with self-oiling bearings show how little lubricant is required for extensive work as compared with the old-style open bearings where at least 90 per cent. of the oil was wasted. It has been proven by careful tests that on ordinary bearings fully that amount of oil was wasted, and only 10 per cent. was actually consumed in lubricating the machinery.

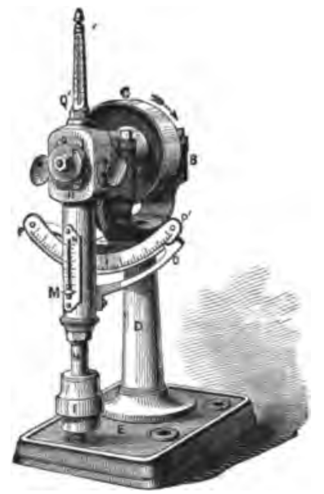
The improvements in lubricating direct-connected engines and dynamos, the journal being provided with a basin or tank to catch the oil, proves how little oil is actually used for lubrication, as in one case on record as follows: In starting, 6 pints of oil were put in the tank, and after a run of 6 weeks, with very few stops, the tank was found to contain 5¼ pints, consuming just ¾ of a pint of oil in a 6 weeks' run.

The gravity of an oil is the thickness or the amount or body it possesses, and is measured by a Baumme scale hydrometer, usually at a temperature of 60° F. The oil is placed in the measuring jar, the hydrometer lowered into the fluid, and the scale records the degree of gravity it possesses.

For the fire-test, the oil is placed in a small iron dish, with a thermometer bulb immersed in it and held in an upright position. The heat is applied under the dish by means of a Bunsen burner until it reaches the point at which the operator expects it to vaporize. Then a lighted taper is passed around the edge of the bowl, and if the vapor that rises from the heated oil flashes, the temperature recorded on the thermometer is the flash point. We can continue to apply the heat until

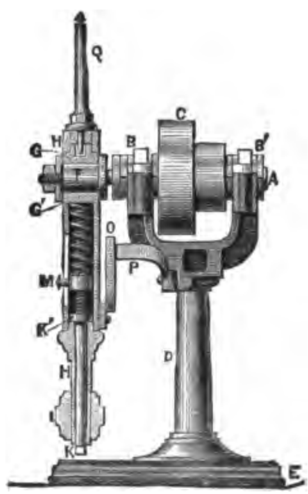
the oil takes fire and then note the temperature again. This is the fire-test.

Viscosity is the term used to denote the efficacy or active principle of an oil



to overcome friction. The word viscosity is derived from the word viscous, or sticky, but the term as applied to oil does not necessarily mean that an oil of a high degree of viscosity is sticky, but, more properly, that it possesses such cohesive properties that it remains in circulation between the metal surfaces of the shaft and bearing, permitting the shaft to move at a high velocity with a minimum amount of friction. To determine the viscosity of a lubricating oil, an instrument called a viscosimeter is used, which measures the drops per minute that are allowed to pass through a small outlet at a given temperature, usually 150° F., and this varies according to the consistency of the oil. There are several different makes of this instrument, none of them giving uniform results, and tests made in this way are generally more or less inaccurate. The most satisfactory method of determining the active principle of a lubricating oil is by means of the testing machine invented by Prof. Robert H. Thurston.

The Thurston oil-testing machine, as illustrated in the accompanying figures, consists of a shaft supported by two stationary journals and carrying a loose journal on one end, on which a pendulum is suspended. On the top is a thermometer for recording temperature. The adjustment of the pendulum can be made to correspond with any pressure that is required in a similar bearing where the oil tested is to be used. The dial indicates the degree of deflection which the lubricant allows the pendulum to oscillate. It also contains a speed indicator with which the number of revolutions per minute can be recorded. It will also determine the liability of oil to gum. This machine is used extensively by our large corporations, the United States Army and Navy departments,



and steamship companies, and is considered by experts in that line to be the best method for the testing of lubricating material for practical use.

THE SCIENCE OF WEIGHING

T. H. REARDON

THE term weight is a measure of the gravitational force which draws a body towards the center of the earth, and the accurate measurement of the amount of force exerted in a particular case is the object of all weighing apparatus, no matter whether it is the 100-ton scales for weighing a large locomotive, or the laboratory balance that is sensitive to the weight of a thousandth part of a grain.

In the construction of platform scales that are generally used for weighing, the principle of leverage is made use of, the construction being such that a pound weight placed on the hanger will balance either 100 or 1,000 lb. on the platform. This ratio always exists in Fairbank's Standard Scales, and a knowledge of this ratio between the load on the platform and the load on the hanger is of importance in more than one way.

In the first place if it should become necessary to weigh a load greater than the stock of weights on hand would permit, knowing that a pound on the hanger represents 100 or 1,000 lb. on the platform, there is absolutely no difficulty in making weights to meet such an emergency, by simply weighing up one or two pound pieces of any suitable material and using such pieces for weights. Of course, in using this scheme proper regard for the strength of the scales should be observed. The writer had occasion to weigh an article in the laboratory a short time since of about 4 oz., the capacity of the balance being only 3.5 oz. A silver dollar was weighed up accurately, and after ascertaining its weight, it was put in the scale pan and used as a weight in the operation.

The usual method of weighing the unknown weight is on the scale platform, but we may invert the process by placing the unknown weight (a small article, of course) on the hanger and placing just enough weight on the platform to make the scales balance; then remove the light article from the hanger, weigh what you have on the platform, and divide this weight by 100 or 1,000, i. e., the ratio of the platform load to the hanger load, and you have the weight of an article that could not be weighed on a large scale in the usual manner. The writer uses a modification of this method that is best illustrated by means of an example: Weigh yourself accurately and remain on the scales; place, say, a letter it is desired to weigh on the hanger and weigh yourself again. We will suppose the first weight was 160 and the second weight was 135; then, 160 minus 135 equals 25, and 25 divided by 1,000 equals .025 lb., or multiplying by 16 equals .40 oz., the weight of the letter.

The refinements in weighing that find place in the laboratory and in delicate methods of scientific research have, of course, no particular interest for the practical man who only needs results that are fairly accurate and that are quickly obtained. Still, however, we often hear persons speak of the exact weight of something they have weighed or seen weighed. It may interest such persons to know that there is no balance in existence that can give the absolutely correct weight of any substance. The reasons for this are obvious: while friction of the bearings in a delicate balance is indeed a small thing, it is not by any means reduced to zero.

FLYWHEEL ACCIDENT

THE bursting of a 4-ton 14-foot cast-iron flywheel, cast in sections, attached to an 80-horsepower engine, at the plant of the F. B. Tait Manufacturing Co., Decatur, Ill., September 15, caused general havoc to the buildings and machinery, and a number of people in and near the plant had narrow escapes from death or injury. The wrecked engine was a 16 in. × 24 in. slide valve, throttle control, running at 85½ revolutions per minute, manufactured by the Union Iron Works, of Decatur. The engine room is on the first floor and about the center of a two-story brick building, enclosed in a brick-walled room 12 × 20, over which extended heavy wooden joists 10 × 14, and countershafts for the governor belts. A number of the employes were on the first floor moving about and at the benches. The engineer, Larkin Wheeler, had been in the engine room a few minutes before the catastrophe, and was in the boiler room, 40 feet distant, when he heard the engine begin to race. Instinctively Wheeler knew that the engine was running away, and he rushed through the shop to the south door of the engine room, bent on shutting off the steam. At the moment of entering the door a flying piece of iron just missed Wheeler's head, and a fraction of a minute later there was a crashing report, like a terrific boiler explosion, followed by the crashing of heavy timbers and the falling of brick walls, the dust of lime and sand filling the room; and then all was still after the steam was shut off.

The engine was equipped with the common throttling governor, without the automatic stop. The accident was caused by the breakage of the governor belt between the engine shaft and the countershaft, causing the sectional flywheel to increase its momentum from 85½ to 300 or more revolutions per minute. The increased momentum caused the heavy bolts holding the sections of the wheel together to break, and the castings, each weighing 350 lb., went flying with crushing force through the brick walls up through the floor and metal roof, ascending to a height of 75 feet, one piece flying through the roof, across the street over 2 two-story dwellings, and plunging into the basement of the third house, 350 feet distant. Another section of equal weight went through the factory window across the street, digging a hole in the earth, and finally lodging in the yard, while the engine room was completely wrecked.

HIGH-SPEED TELEGRAPH SYSTEM

BRIEF DESCRIPTION, OPERATION, AND PROPOSED USES OF THE SYSTEM

THE latest improved system of high-speed telegraphy, invented by Patrick B. Delany, of New Jersey, is capable of transmitting from 100 to 8,000 words per minute over a single wire—the speed depending upon the distance and the electrical properties of the line, that is, upon the electrostatic capacity, resistance, and inductance of the circuit.

Eight thousand words per minute can be recorded over a line of 50 miles, while 100 words per minute would be about the limit between New York and San Francisco over a copper wire (about No. 8, B. & S.), such as used for long distance telephony.

The operation of this system may be briefly described as follows: The messages are first punched on a paper tape

by a so-called perforating machine. This tape is then passed through a transmitting device which closes the line circuit through the perforations in the tape and thus transmits electrical impulses representing dots and dashes. At the receiving station these impulses are recorded on a chemically-prepared tape in dots and dashes of the Morse code. The transmission being purely mechanical, after the perforated tape has been prepared, and the recording being effected electrolytically by the passage of a current through the chemically-prepared tape, the speed of transmission is only limited by the electrical properties of the line wire itself. In most other systems electromagnets in the line circuit must be energized, armatures moved, and inertia overcome, thereby greatly restricting the rate of working and the distance of direct operation (that is, without the use of repeaters). Heretofore, tapes for automatic transmission have been prepared either by keyboard instruments or by three-keyed machines, such as the well-known Wheatstone puncher, which has one key, by the depression of which suitable holes are punched in the tape to transmit a dot, the depression of another key punches suitable holes for a dash, and a third key, suitable holes for a space. These machines require special training or a separate staff of employes for their operation.

The newest Delany Perforating Machine is controlled by one ordinary Morse key, so that any operator can at once become a perforating operator, his work being precisely the same, whether sending a message over a line in the usual way, or sending it into the perforating machine. The speed of perforation depends upon the exertions of the operator in working the key. It may vary from 15 to 45 words per minute. Fifty or more operators may be employed up to their full capacity in perforating messages for one automatic transmitter and one wire will carry them all.

If the business between any two points should not require so great a speed, the perforated tape and automatic transmitter may be used to operate an ordinary relay and sounder at the receiving end, the receiving being by sound in the ordinary way, but at a speed up to the best ability of an expert receiving operator using a typewriter. This would be about double the average rate of hand sending, because an operator using a typewriter can receive twice as fast as the average operator can send. The speed of automatic transmission can be readily regulated to suit the ability of the receiving operator.

Another advantage of the Delany perforator is that it can be worked hundreds of miles away from the key. An operator in New York may perforate a tape in Chicago that could be used for retransmission to Omaha, and so on to San Francisco. Branch and suburban offices could perforate tapes in a central office where the messages so prepared could be automatically transmitted at high speed over trunk lines to their destination. With this fast system it has been proposed to establish lines for the transmission of ordinary mail matter at rates averaging about 15 cents for 50 words for distances of 1,000 miles. This would be much superior to the use of special delivery letters and cheaper than ordinary telegrams. It could also be used by the press associations for the cheaper distribution of news. This system of Delany is now in regular use by several large railroads.

EDITORIAL COMMENT

The Aeronautical World Co., which sprung into existence in Glenville, O., has attacked the question of "the conquest of the air by man" from a new position. In this publication a system of cooperation in the matter of ideas is to be carried on in the hope that the serious misconceptions and errors which now beset airship promoters may be successfully overcome and a sailing craft devised which will float through space with the speed of a bird and the capabilities of an ocean liner.

This unique publication, which is published monthly, announces that its columns will be devoted exclusively to the discussion of aeronautics.

"It is the general belief of the most eminent scientists and thinkers," the journal says, "that successful aerial navigation is possible and simply awaits the development of a properly designed machine."

Mentioned in the first number are no less than a score of aerial inventions either wholly or partially completed, for each of which it is claimed that there is hope of a practical solution of the problem. And the possibilities of flight through the air are painted in glowing terms.

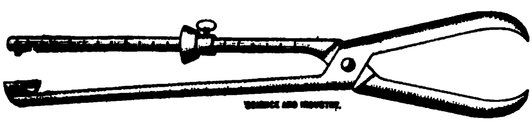
Taking up the practical question of the invention of the air ship itself, the journal says:

"The successful aerial machine will be vastly more stable than a bicyle, and man will much more readily learn to rely on it for support and safe transit, for the reason that his center of gravity will be placed below the center of support, where he can more easily, conveniently, and safely rock his supporting aeroplane surface than he could maintain his balance on a bicycle or rock a canoe on the water.

"The most practical and efficient aerial machine will be one instinctively controlled by its intelligent ballast, the aeronaut, who will be located low down and near the center axis of the system, so that by instinct or design he can move to alter the set of his aeroplane surfaces and so vary their resistance. The movements will be made as quickly and unconsciously as a person when walking trips and recovers his balance or places one foot before the other."

In reply to several inquiries on the subject we would state that the top used in the construction of the mechanical stirring rod, described in the September number, can be purchased from J. H. Bunnell & Co., 20 Park Place, New York, N. Y.

The accompanying illustration shows an ingenious device for cutting gauge glasses to measure. One arm has a scale divided in inches and fractions of an inch, a slide top with a set screw, and a rotary cutter at the end. This arm is inserted in the glass tube and held against the slide top which is set at the proper point on the scale, the outside of the tube resting in the circled



end of the other arm. With a slight pressure on the handles and a rotation of the tube, the cutter makes an even cut around the inside of the tube, and a very little pressure breaks it off. The instrument is manufactured by A. E. Hunt, Scranton, Pa.

In the October supplement the letter *D* was accidentally omitted from the drawing. This letter should indicate the thickness of the head of the first

bolt from the shank up to where the head is rounded off.

The supplement accompanying this issue consists of a table giving the allowable carrying capacities of rubber-covered and waterproof wires ranging in size from No. 18 to No. 0000, B. & S. gauge, and of stranded cables up to 2,000,000 circular mils.

In our October issue, page 539, mention is made of a turbine making 200,000 revolutions per minute. This is a typographical error, and should be 20,000.

BOOK REVIEWS AND TRADE NOTES

THE PROFESSOR ON SHIPBOARD. By C. A. McAllister. Published by Marine Engineering, New York. Price $1.00.

The story which recently appeared in Marine Engineering, entitled "The Professor on Shipboard," has been published in book form, making a handsome volume of over 100 pages. Nothing has ever been published that contains so much every-day information which every engineer ought to know, as this book. Therefore, no working engineer or man connected with marine work can read any book that will be of such value to him. In addition to the practical information it contains, it is a most readable story of life at sea. Briefly told, the story is of a college professor of engineering, who has many excellent ideas, some of which are rather theoretical, who makes the trip to Brazil and back with his brother, chief engineer of a steamship, a man of much practical experience. The discussions bring out some strong points which deeply interest every man who has anything to do with a steam plant.

HISTORICAL NUGGETS. Published by Fords, Howard & Hulbert, New York. Price 45 cents.

The object of this gathering of ideas from expert historical and critical writers is to gain a conception of the demands of true "historical art." The theme of the book is "the true aim and method of artistic historical writing."

THE TREATMENT OF STEEL, third edition, revised and reprinted by the Crucible Steel Co. of America, Pittsburg, Pa. Price 75 cents.

The title page of this work states that it is a compilation from publications of the Crescent Steel Co. on heating, annealing, forging, hardening, and tempering, and on the use of furnaces; also a chapter on hardening and tempering from a work by George Ede, Woolwitch Arsenal, England. The book contains a wealth of valuable information on one of the most important branches of the engineering industry. It is of interest and worth to every engineer, and owing to its attractive appearance it is an ornament to any library. We are requested to say by the publishers that the book is not for free distribution, but will be supplied at the cost price of 75 cents.

TELEGRAPHERS OF TODAY. By John B. Taltavall. Published by the Telegraph Age, New York. Price $5.00.

This is descriptive, historical, and biographical of the telegraphic profession of today, giving sketches of the careers of all the living successful telegraph experts of America. Among many others it contains complete biographies of such well-known men as Hon. Alonzo B. Cornell, Andrew Carnegie, and Thomas A. Edison.

DON'T WORRY NUGGETS. Compiled by Jeanne G. Pennington. Published by Fords, Howard & Hulbert, New York. Price 45 cents.

This little book will help any one to dispel that greatest enemy of success—worry. It is a collection of the choicest and most cheerful sayings of Epictetus, Robert Browning, George Eliot, and Ralph Waldo Emerson. Cheerfulness is such a valuable asset that our readers will find this a good book to own.

EVERY LIVING CREATURE. By Ralph Waldo Trine. Published by T. Y. Crowell & Co., New York. Price 35 cents.

An eloquent appeal and an able argument for justice and mercy to our dumb fellow creatures. A good book for those whose characters are being formed, and for all who love justice and right.

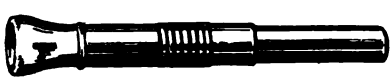
The H. B. Smith Machine Co. have just issued a large catalogue of wood-working machinery, which is more than an ordinary catalogue. This company is one of the oldest in the manufacture of wood-working machinery, and build a large variety of fine tools. The catalogue contains 619 pages. The illustrations are remarkably clear. Each machine, and in many instances the principal parts of the machine, are illustrated

and described clearly and fully. The first 32 pages of the catalogue are printed on tinted paper, and in them are contained statements concerning the company, its medals, diplomas, etc. which it has taken at various expositions, description of the company's testing room, many features about their plant, a notice of their paper, The Mechanic, a statement as to the object in printing it, a statement of their facilities for manufacturing, and the guarantee which goes with their machines. The balance of the catalogue contains descriptions and illustrations of the individual machines. From the pages of this catalogue one could pick out all the tools necessary to equip the finest kind of a modern wood-working establishment. This catalogue is the fifty-second edition and is so complete that a detailed description of it would be out of the question.

The Mechanical Appliance Co., of Milwaukee, Wis., have issued a couple of attractive little circulars descriptive of the motors and generators manufactured by them.

An ingenious card device for displaying the colors of Dixon's Silica-Graphite Paint in such manner as will permit of an exact idea of each color, is being issued by the Joseph Dixon Crucible Co., Jersey City, N. J. The color chart carries with it suggestions as to the class of construction that can be protected with this paint, also instructions as to best methods of applying protective paint. The new color chart can be secured by request to the Joseph Dixon Crucible Co., Jersey City, N. J.

A very neat cigar perforator is shown in the accompanying illustration. It is nicely nickel plated, and small enough to be easily carried in the vest pocket. To operate it, place the cigar in the opening in the end of the perforator and press the sliding end in as far as possible, turn the cigar slightly, and withdraw cigar from perforator before releasing the finger from the sliding end of perforator. A very small core is taken from the center of cigar, which allows the smoke to flow freely through, and it is claimed that the cigar does not become strong, and



has less nicotine than when the end is only clipped off. One of the perforators will be sent free to any address, upon request, by the Eastern Granite Roofing Co., Suit 87, Gerken Building, New York. This company reports that trade has been exceptionally busy the past six months, and that they will show a very heavy increase over last year's business.

We have just received from the Smith & Hemenway Co., of 296 Broadway, New York

City, a copy of the fourth edition of the Green Book of Hardware Specialties. This book is considerably larger than their last one. It contains 145 pages of highly interesting matter, and is illustrated throughout by a number of half-tones. This book contains illustrations of all articles manufactured by the Smith & Hemenway and Utica Drop Forge & Tool companies. It is printed on green paper and each page has a very attractive border in orange around it. This book would be quite an addition to the catalogue file of any up-to-date dealer. The accompanying illustration gives an idea of the appearance of the book.

The Rochester Radiator Co., of Rochester, N. Y., are keeping in touch with their former inquirers and buyers by sending them a little souvenir which consists of a booklet of valuable receipts, puzzles, conundrums, and bright sayings of witty people. This is unique and will certainly be read and kept. They have lately incorporated. The officers are: W. M. Hunt, president, and F. E. Williams, secretary and treasurer.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

MECHANICAL

(285) I have a compound duplex Worthington pump, size 14 × 20 × 12 × 10, which has run without a jar or pound for a number of years until about one week ago, when a pound developed in the water end. Can you suggest a remedy or tell me where I can find the trouble?

W. S. N., Denver, Colo.

Ans.—Pounding in a pump is usually due to one of the three following causes: striking of the piston against cylinder head, broken or deranged water valves, or water hammer in the pipe connections. Without a personal examination of the pump it is impossible to state which of these three causes is making you trouble. Since, however, the pump has worked quietly a long time, it is safe to say that water hammer is not the cause. We suggest that you examine the pump for broken valves in the water end, and if everything is all right, reset the steam valves.

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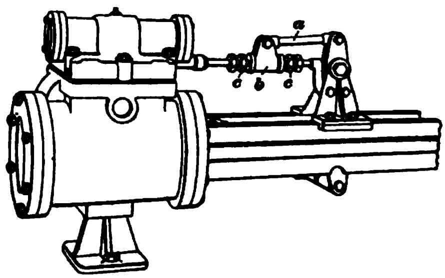
(286) (*a*) Kindly explain the "lost motion between the jam nuts and valve" in answer 188, page 385, July number. (*b*) I have a duplex Worthington pump of 6″ normal stroke that gives only $4\frac{3}{4}''$ plunger stroke. What shall I do to give it full stroke? J. M. J., Brooklyn, N. Y.

Ans.—(*a*) In nearly all duplex pumps, the motion for operating the valves is transmitted through a link to a loose-fitting sleeve that slides on the valve stem. At each end of the sleeve are jam nuts that can be adjusted in position so that the sleeve travels part of the valve stroke before it moves the valve stem. The amount that the sleeve travels without moving the valve stem is called "lost motion." Referring to the cut, *a* is the link that transmits the motion to the sleeve *b*, *c c* are the jam nuts whose position regulates the amount of lost motion. If it is desired to reduce the amount of valve travel, the nuts are screwed farther apart, thus increasing the lost motion; while to increase the valve travel the nuts are brought nearer together. (*b*)



The motion of a plunger stops as soon as cut-off takes place in the steam cylinder on that side; consequently, if the plunger stops when it has traveled $4\frac{3}{4}''$ instead of 6″, it means that cut-off has taken place too early. The remedy is to move the jam nuts farther apart on the side of the short stroke.

***

(287) (*a*) Is the rise in pressure at the explosion in the cylinder of a gasoline engine due entirely to the heat generated, or is it partly due to the chemical change in the gases? (*b*) What variation of voltage is allowable in a dynamo for sparking a gasoline engine and how is the voltage regulated? G. E. M., Grand Rapids, Mich.

Ans.—(*a*) It is due wholly to the rise in temperature of the gases and not at all to any chemical changes. The only chemical change that takes place within the cylinder is the oxidation or burning of the gasoline. This takes place so rapidly that it is termed an explosion. The heat generated by the combustion causes a very great rise in the temperature of the gases and this causes an increase in pressure. This pressure acting on the piston produces work. (*b*) If the dynamo is operating properly, a variation of 8 to 10 per cent. either way should not do any harm. Much depends, however, on the type of dynamo and whether it has plenty of capacity for the work or not. The best

method of regulating the voltage depends upon the style of dynamo under consideration. If it is a magneto machine the field strength cannot be varied and the simplest way is to insert an adjustable resistance in series with the armature. If a small shunt-wound generator is used you can insert an adjustable resistance in series with the field coils.

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(288) Will you please inform me how to set the valves on a link-motion engine?

W. S., Livingston, Mont.

Ans.—Setting a slide valve is really a very simple operation, and more a matter of reasoning than of rule. If the Stephenson link motion is used, the usual procedure is as follows: The link is thrown in full gear ahead and the crank placed on the head-end dead center. Next, the two eccentrics are turned around on the shaft until they have about the proper angular advance as near as can be judged by eye. Then the valve stem is lengthened or shortened until the head-end steam edge of the valve is just about to uncover the head-end steam port. The crank may now be placed on the crank-end dead center. The distance the crank-end steam port is opened, or the distance the crank-end steam edge of the valve has traveled beyond the crank-end edge of the crank-end steam port, is measured. In the first case considered, the valve should be moved toward the crank end one-half the distance the port is opened; in the second case, the valve should be moved toward the head end one-half the distance the valve has traveled past the crank-end steam port. The valve is now adjusted so that it will travel equally both ways from its mid-position. Next, the go-ahead eccentric is shifted until the desired lead is obtained, which will be equal at both ends. To set it for the reverse motion, the link is thrown in full gear for the reverse motion, the crank placed successively on the head-end and crank-end centers, and the leads measured. If the sum of the two leads for the reverse motion is equal to the sum of the two leads for the forward motion, the eccentric has the proper angular advance. If the sums of the leads do not agree, the reverse eccentric is shifted until they do. Having placed the eccentric in its proper position, the crank is placed on the head-end center, and the head-end lead is measured. Should it be found to be less than that obtained in the forward motion, the eccentric rod of the reverse eccentric must be shortened an amount equal to the difference of the two leads for the two motions. Should the head-end lead be found to exceed that of the forward motion, the reverse eccentric rod must be lengthened an amount equal to the difference of the two leads for the two motions. Having done this, the valve will be set correctly for the two motions. In setting the valves of an engine fitted with link motion, it should be remembered that moving the eccentric only changes the amount of lead, while moving the valve on the stem serves to make it travel equally in both directions from its mid-position. In some instances the valve cannot be moved on the valve stem. In that case all adjustments for equal travel, etc. must be made by lengthening or shortening the eccentric rods. It often happens that an engine is run for the greater part of the time with the link in the position that will give the most economical point of cut-off for the load to be carried; since the lead with the Stephenson link varies as the position of the link changes, it will generally be found that if the valve is set with the link in full-gear position the lead will not be entirely satisfactory for the usual running position. In such a case it will be well to set the valve with the link in the running position. The Stephenson gear with a straight link is sometimes used on engines that, like some hoisting engines, are intended to run only with the link in full gear.

ELECTRICAL

(289) Suppose a telegraph line has 100 cells of battery. Which of the three following arrangements will produce the best working line: (1) 50 cells at each end; (2) 75 at one end and 25 at the other end; (3) 10 cells at each of 10 stations?

W. A. D., Orizaba, Mex.

Ans.—With a perfectly insulated line it makes no difference where the cells are placed in the line circuit. As this is never the case, it is not best, except on relatively short lines, to put all the cells at one end, and it is generally best to put half the total number of cells at each end. However, sending in one direction may be accomplished over a line from which the leakage is unusually large and over which it may be impossible to work satisfactorily in both directions by concentrating all the battery at the sending end. Hence, the more leakage the larger should be the number of cells at the sending end. If the cells are equally divided among 10 stations, then any 2 stations equally distant will work equally well. As to whether they will work well enough will depend upon the amount of leakage and the distance between the sending and receiving stations. With reasonably good line insulation half the total number of cells at each end would be the best arrangement, taking all things into consideration. With reasonably good line insulation and neglecting the commercial advantage of concentrating all the cells at the two ends, which simplifies connections, and places the cells under the care of fewer persons,

the division of the cells equally among 10 stations would give the best average results at all stations.

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(290) (*a*) On the testing board described on page 206 of the April number is 1,000-volts pressure between one side of the line after the current passes through the lamps, in the puncture test, as severe as 1,000 volts direct from the line? (*b*) Is there anything published on the chemistry of insulating materials used for electrical machinery? (*c*) What is electrical synthesis?

R. E. W., San Antonio, Texas.

ANS.—(*a*) If absolutely no current flowed into the device under test, the E. M. F. applied to it would be 1,000 volts, whether the lamps were in circuit or not, because there would be no drop in the lamps. The insulation of the device might be perfect, and yet a small current might flow due to electrostatic capacity. If this were so, there would be a drop in voltage through the lamps, and the voltage applied to the apparatus would be less than 1,000 volts. Of course if the insulation broke down the current would not be limited without the lamps, as it would with them. Taking everything into account the test without the lamps should be considered more severe than the test with them. (*b*) We do not know of any treatise on this subject. (*c*) Electrical synthesis is the combining of two or more substances to form chemical compounds, this combination being brought about by means of the electric current. For example, if an electrical discharge is passed through air a certain quantity of the oxygen of the air is made to combine with nitrogen, and nitric oxide NO and nitrogen peroxide NO_2 are formed. This would be a case of electrical synthesis.

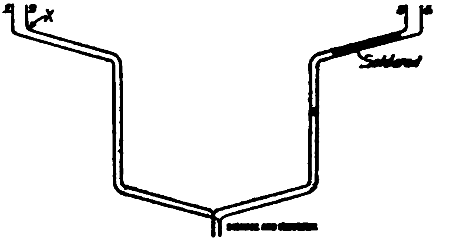
***

(291) How can the noise caused by telephone wires, when they are fastened to a building, be prevented?

H. H., Mooseland, Minn.

ANS.—For this purpose a damper is sometimes used. The damper may consist of a rubber cylinder, about 4 inches long and ½ inch in diameter, and is split lengthwise. After the rubber cylinder is in place on the conductor it is bound spirally with fine wire to keep it in place. The rubber damper containing the conductor may then be placed upon an insulator, or the wire may be tied to the insulator in the usual manner and the damper may be attached by a wire around it to a damper on a neighboring conductor, or to the fixture, chimney, or pole. The object of the damper is to prevent the mechanical communication of the vibration of the conductor to the building.

(292) (*a*) A 10-H. P. induction motor used for starting a 350-K. W. rotary converter was burnt out. The machine was in an electric railway substation. Could the rotary converter be started without the motor or not? (*b*) In winding a direct-current armature of about 40 H. P., using strap coils with two leads at each end, we had an idle bar in the commutator. We cut No. *2* lead off at point marked x in the accompanying figure and soldered leads *3* and *4* together. The bar or segment that lead No. *4* went into had no bottom lead in it. Please give a full explanation of this, as it is done very frequently at the shops of the Westinghouse Electric & Mf'g Co. (*c*) A man in Chicago has invented a method of running street cars without motors. The



car is operated by electromagnets placed between the rails and which are excited so as to draw the car along. Please explain the wiring of the magnets and the car. Please give full explanation of the electromagnet used on the car.

G. C. R., Pittsburg, Pa.

ANS.—(*a*) Yes; the rotary could be started by connecting the collector rings to the transformers and supplying it with alternating current. Rotaries are frequently started in this way, though they take quite a large current from the line. Means are usually provided for cutting down the alternating E. M. F. when it is first applied, and then raising it as the machine comes up to speed. If a rotary had to be started in this way in case of a breakdown it could be thrown directly on the alternating current, but in the case of a large machine this might cause considerable disturbance. It would be better to cut down the voltage by means of a temporary resistance of some kind. (*b*) Space does not permit us to give a full explanation of this question, as it would involve a general discussion of multipolar two-circuit armature windings. Briefly, in windings of this type, the number of armature coils must bear a certain relation to the number of poles in order that the winding shall connect up properly. For example, in a series-wound drum the number of coils cannot be divisible by the number of poles and have the winding connect up properly. In order to obtain a number of coils to satisfy

the required conditions, it is frequently necessary to cut out one coil as you describe, this coil being dead but left in position so as to maintain the mechanical balance of the armature. (*c*) No details of this system have as yet been published so far as we are aware, and we are, therefore, unable to give a diagram of the connections. This method of operating street railways has cropped up regularly for some years back, and nothing has ever came of it. The amount of power required to operate a road by this means would be enormous and there is little likelihood of it superseding the electric motor.

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(293) Please inform me how you get a reading on the voltmeter in the figure relating to Question 241 of the September issue. If the insulation of *A* is good, will you get any deflection on the voltmeter, or do you use a ground on *A*? As I understand it, you only ground the voltmeter. If the insulation on *A* is weak, you get a deflection; if good, there is none. I use this formula and in some cases I get a deflection, but did not know how I got it, as the circuit would not show a ground with the magneto.

R. C., Annapolis, Md.

ANS.—Your understanding of the test is correct. One side of the voltmeter is grounded and the other side connected to one of the lines. If a deflection results it shows that there is a leak on the line to which the voltmeter is not connected. You must remember that this method of testing is much more delicate than the magneto test, and you might easily get a voltmeter deflection and yet have such a high insulation resistance that your magneto would not ring through it. Very few lines are so perfectly insulated that you would not get some deflection. The insulation would have to be exceedingly high in order to cut down the deflection to an amount too small to read.

***

(294) I have been asked the following question: To what point on the exciter for an alternator is a rubber-covered copper wire attached, the other end of which is fastened to the bus-bar on the switchboard?

F. A. B., St. Joseph, Mich.

ANS.—This question is not put at all clearly. Presumably one of the exciter bus-bars is meant, because a wire from the exciter could not be run to the main alternator bus-bars. Probably the wire meant is the shunt-field wire of the exciter. One end of the exciter field usually connects to one brush of the exciter and the other end connects to a small terminal block on the exciter connecting board. From this block a rubber-covered wire is run to the switchboard and, after passing through the field rheostat, is connected to the exciter bus-bar or switch terminal that connects to the other brush, i. e., to the brush to which the first mentioned end of the shunt field is not connected. Probably this is the wire meant, but the question is not stated definitely enough to tell just what connection is intended.

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(295) (*a*) What telephone systems are in operation in London, Liverpool, and Birmingham, England? (*b*) Is the Bell, central energy, or the automatic system that requires no operators in use, or is either being considered? C. A. W., Troy, N. Y.

ANS.—(*a*) The telephone system used in London by the National British Telephone Co. is a central energy system. It is a combination of the Western Electric and Kellogg systems. For diagrams of connections and full description of this system see the Electrical World and Engineer, April 5, 1902. The telephone system in London of the British Post Office is a modification of the Western Electric Co.'s central energy system. In spite of considerable searching of periodicals of the last few years, we have been unable to find out what systems are in use in Liverpool and Birmingham. (*b*) It is unreasonable to expect any one outside of the authorities of the cities themselves to know what systems such cities are considering, especially where the cities are so far off. The automatic system, to the best of our knowledge, is not in use in any of the cities you mention.

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(296) Will you please tell me how to construct a choke coil for an arc lamp? I have 104-voltage alternating current.

W. R., Harrisburg, Ill.

ANS.—You have not given enough data to enable us to give any very exact information as to dimensions, but you might try making up a coil on the general plan described for constructing the small transformer in the July issue of SCIENCE AND INDUSTRY. Cut the strips for the core 1½ inches wide and build them up to a thickness of 1½ inches. Wind on a coil of about 300 turns of No. 12 B. & S. wire. In winding this, bring out taps every 20 turns for the last 140 turns, so that you can try different numbers of turns in order to find out which number gives the best results.

***

(297) Please inform me whether the transformer described in the July issue is a step-up or a step-down transformer.

W. W. S., Harrisburg, Pa.

ANS.—The transformer can be used either way. If supplied with current at low potential it will step up, or if supplied with current at high pressure it will step down. Ordinarily the transformer would be used to step down, because the alternating current is usually supplied from the street at about 100- to 110-volt pressure.

(298) Is it necessary to cross-connect the commutators of all four-pole machines, or is it resorted to as a means of bringing up the efficiency of ill-constructed machines?

F. G. F., Erie, Pa.

ANS.—No, it is not necessary to cross-connect the commutators of all four-pole dynamos; in fact, the majority of four-pole machines are not cross-connected. Cross-connecting has no bearing on the efficiency. The type of winding determines whether or not cross-connections are needed, and efficient machines can be built either with or without them.

MISCELLANEOUS

(299) (*a*) In Fig. 1, find the length of radius DC or x, such that the area of the circular lune $CMED$ is equal to the area of the circle $CDEN$. (*b*) How can a rectangular piece of cardboard 2″ × 10″ be cut so as to form a square?

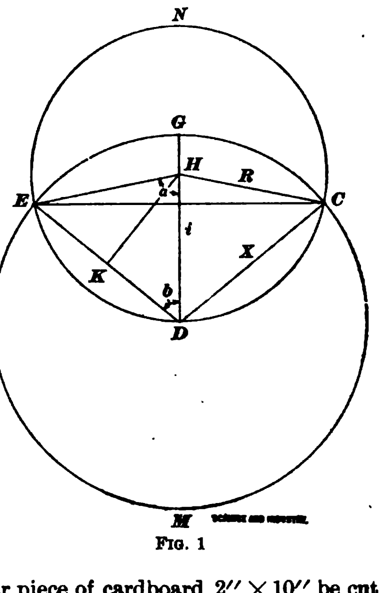


FIG. 1

W. R. S., Orange, Tex.

ANS.—(*a*) Let the radius of the given circle $DCNE$ be R. From the figure $180° = a + 2b$. Hence, $b = 90° - \frac{a}{2}$, or when the angles are expressed in radians for circle whose radius is 1, $b = \frac{\pi - a}{2}$. Again, $DK = \frac{1}{2} DE = \frac{1}{2} x = \sin\frac{a}{2} \times HD = \sin\frac{a}{2} \times R$. Hence, $x = 2R\sin\frac{a}{2}$. Then the area of the segment $CEDC = R^2 a - \frac{R^2}{2}\sin 2a$; and the area of the segment $CGEI = x^2 b - \frac{x^2}{2}\sin 2b$. Substituting $2R\sin\frac{a}{2}$ for x, and $\frac{\pi - a}{2}$ for b, segment $CGEI = 4R^2\sin^2\frac{a}{2}\left[\frac{\pi - a}{2} - \frac{1}{2}\sin(\pi - a)\right]$. Hence, area of the figure $CGEDC = R^2\left(a - \frac{1}{2}\sin 2a\right) + 2R^2\sin^2\frac{a}{2}\left[\pi - a - \sin(\pi - a)\right]$. Then by the conditions of the problem, $\pi x^2 = \pi R^2 + R^2\left\{a - \frac{1}{2}\sin 2a + 2\sin^2\frac{a}{2}\left[\pi - a - \sin(\pi - a)\right]\right\}$. (1). Then, substituting $4R^2\sin^2\frac{a}{2}$ for x^2, $\sin a$ for $\sin(\pi - a)$, $\cos a$ for $1 - 2\sin^2 a$, $2\sin a\cos a$ for $\sin 2a$ and reducing, equation (1) becomes $\sin a = (\pi - a)\cos a$. This equation is solved by trial and a is found to be 77° 27′ 12″. Then, since $x = 2R\sin\frac{a}{2}$, $x = 1.2512\,R$. (*b*) Let Fig. 2 be the rectangle that is to be cut so as to form a square. The area of this rectangle is 2 × 10 or 20 square inches. Then the side of a square of same area is $\sqrt{20}$, or $2\sqrt{5}$ inches. Since $\sqrt{2^2 + 4^2} = 2\sqrt{5}$; the side of the required square is equal to the hypotenuse of a right angled triangle, whose base is 4 inches and whose altitude is 2 inches. Hence, the two rectangles AC and DF are cut from the given rectangle. The part EG which is left is a square. Then, the 2″ × 4″ rectangles are each cut into two equal triangles, as shown by the dotted lines AC and DF. When the four triangles so formed are placed about the 2″ × 2″ square, as shown in Fig. 3, the required square is formed.

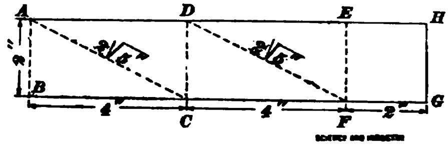


FIG. 2

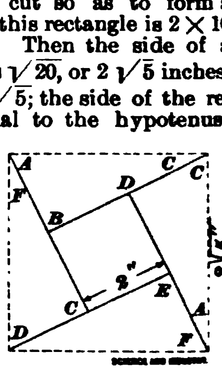


FIG. 3

(300) If a heavy sphere 8 inches in diameter, be put into a conical vessel, full of water, whose diameter is 10 inches and altitude 12 inches, how many cubic inches of water will run over?

W. D., Hudson, Mass.

ANS.—The accompanying figure shows a section made by a plane passing through the center C of the sphere and the apex A of the conical vessel. Draw CG from the center of the sphere to the point of tangency of the sphere and AB an element of the cone. Then the triangles ABH and ACG are right triangles, and since they have the acute angle HAB common, they are similar.

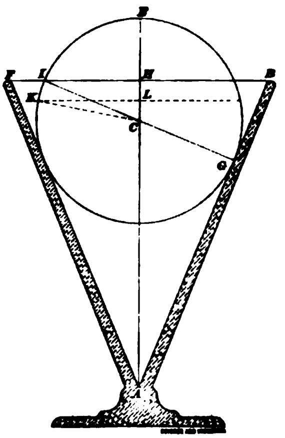
Hence, $AB : AC :: HB : CG.$ (1)

But by the conditions,

$HB = \frac{1}{2} \times 10'' = 5''$; $CG = \frac{1}{2} \times 8'' = 4''$;

and $AB = \sqrt{12^2 + 5^2} = 13''$.

Substituting these values in (1), $AC = 10.4''$. Then, $HC = 12'' - 10.4'' = 1.6''$; $HI = \sqrt{4^2 - 1.6^2} = 3.666''$; $CL = \frac{1}{2} \times 1.6'' = .8''$; and $LK = \sqrt{4^2 - .8^2} = 3.919''$. The area of the section of which HI is radius is $\pi \times 3.666^2 = 42.223$ sq. in.; of which KL is radius is $\pi \times 3.919^2 = 48.255$ sq. in.; and of the section of which a radius of the sphere is radius is $\pi \times 4^2 = 50.266$ sq. in. Hence, the volume of the segment of the sphere of which HC is the altitude is $\frac{1}{6} \times 1.6 \times (50.266 + 42.223 + 4 \times 48.255) = 76.136$ cu. in. The volume of half the sphere is 134.041 cu. in. Therefore, the volume of the part of the sphere submerged and consequently the volume of the water that runs over is $76.136 + 134.041 = 210.177$ cu. in. Ans.



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(301) I desire information regarding the design of a rafter member in a structural-steel roof truss. The rafter member is made of two angles, back to back, with a $\frac{5}{16}$-inch gusset plate between them. I have several rolling mill handbooks, but am unable to derive information without assistance from one more experienced. The rafter member is divided into four panels, each panel being 5.4 feet long, and the compressive stress that it is required to support is 39,900 pounds. What size angles are required for this member? O. W. E., Uniontown, Pa.

ANS.—In most of the rolling-mill handbooks they give tables for the safe load on steel angles used as struts or columns, when placed back to back and supported by a gusset plate. From such a table we find that two $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{5}{16}''$ angles, placed back to back, though spaced $\frac{1}{2}$ inch apart will sustain for an unsupported length of 5 feet, $22\frac{1}{2}$ tons, or 45,000 pounds. This is the safe load, and these angles spaced $\frac{5}{16}$ inch apart would provide ample compressive strength for the rafter member in the truss. If you desired to use angles with unequal legs, from a similar table we find that two angles $3\frac{1}{2}'' \times 3'' \times \frac{5}{16}''$ will meet your requirements. These tables are calculated by what is known as the straight-line formula for figuring the strength of columns, which is as follows:

$$S = 13{,}500 - \frac{l}{r},$$

in which S equals the allowable unit compressive stress—that is, the amount of compression each square inch of section in the angles will sustain as a column; l equals the length of the column, and r the least radius of gyration for the two angles placed back to back. The formula given is for soft steel, and for columns having square ends. The formula for fixed ends, which gives a different value, might be used, though in our opinion it is not applicable to the usual roof truss. The value of r may be figured, but the calculations are somewhat involved, and we feel sure that in the handbook which you have there is a table giving the radii of gyration for two angles placed back to back. In applying the formula given the value of l is practically 65 inches, and assuming that two $4\frac{1}{2}'' \times 3'' \times \frac{5}{16}''$ angles are to be used, we find from the table that the least radius of gyration is somewhere between 1.13, which is the value for two angles with their backs touching, and 1.31, which is the value for angles separated $\frac{1}{2}$ inch. We will therefore assume that angles separated $\frac{5}{16}$ inch will have a least radius of gyration of about 1.2. By substituting these values in the formula, $S = 13{,}500 - 50 \times \frac{65}{1.2}$, or 10,800 lb. This value, being the compressive resistance for each square inch of section in the strut, and the area of the two angles being equal to 4.5, the safe resisting strength of the strut equals $10{,}800 \times 4.5$, or 48,600 pounds, which is somewhat in excess of the strength required The formula which has been given is applicable to columns whose length is more than 30 radii of gyration; that is, in this case, 30 times 1.2, or 36 inches. If the strut or column was under this length the safe direct unit compressive stress for structural steel would be employed, and this value is 12,000 pounds. The formula is limited in its use to columns whose length does not exceed 150 radii of gyration, or 45 times the dimension of the least side of the section.

(302) What safe fiber stress is used for concrete when designing a beam of this material? This information is desired for calculating the safe load of foundations made of concrete. F. W. S., Chicago.

ANS.—The transverse strength of concrete is exceedingly low, and varies with the relative proportions of cement and aggregates, with the quality of the cement, and with the age of the concrete. The following table will give the approximate ultimate unit values for concrete subject to transverse stress:

	Pounds
Concrete, Portland cement, 1 month old	100
Concrete, Rosendale cement, 1 month old	50
Concrete, Portland cement, 1 year old	150
Concrete, Rosendale cement, 1 year old	75

In the design of foundations of this material, subject to transverse stress, a factor of safety of from 8 to 10 should be used. The transverse strength of concrete used for foundation footings can be greatly increased by providing the necessary tensile resistance. This is accomplished by embedding steel rods in that portion of the concrete slab, or footing, subjected to tensile stress. The Expanded Metal Fireproofing Co. have recently designed a type of footing that is admirably adapted for spread foundations. The footings consist of concrete reenforced with rolled iron bars of a square section provided with corrugations on the four sides. The sides of the ribs thus formed on the bars are at such an angle with the axis as to preclude the slipping of the bars when embedded in the concrete—that is, the bars are so formed that the angle of friction between the two materials is not exceeded. The Expanded Metal Fireproofing Co. published a very interesting description of these footings, together with a comparison of cost between the reenforced footing and one made of solid concrete, and also the usual type of grillage footing.

***

(303) (*a*) I have in charge a direct current 110-volt 145-ampere dynamo. Can I successfully place in my circuit a Thomson-Rice 2,000-candlepower arc lamp? If so, how can it be done? Can such lamps be put in multiple? (*b*) If a T. H. type L. D. dynamo with automatic regulator is running with 25 lamps and 5 lamps more are added, does the voltage, or current, or both increase? J. H. P., Fremont, O.

ANS.—(*a*) An arc lamp operated from this machine would be connected in parallel. The lamp you mention is probably intended for operation on a series constant-current circuit, and such being the case it cannot very well be operated from a constant-potential machine. Lamps intended for operation in parallel have a different regulating mechanism from those intended for series operation. (*b*) The voltage increases, but the current remains unchanged if the regulator does its work properly.

***

(304) What is gasoline composed of? F. H., Brandon, Ont.

ANS.—Gasoline is one of the products of the fractional distillation of crude petroleum, and consists of the elements hydrogen and carbon.

***

(305) Does a solution of corrosive sublimate give off a gas and disinfect the atmosphere in the same way as chloride of lime? What other disinfectants act in this way? G. E. F., Pittsburg, Pa.

ANS.—No, corrosive sublimate does not give off any fumes that act as disinfectants of the atmosphere; it is an excellent disinfectant when brought in direct contact with infected material. Its solution is used for washing surgical instruments, walls, and floors of sick rooms, etc. To disinfect rooms, bedding, clothing, etc., we would advise formaldehyde, or burning sulphur.

***

(306) What magazine would you recommend for a student of analytical chemistry? E. G., Helena, Mont.

ANS.—We would advise you to subscribe to The Analyst, the journal of the Society of Public Analysts, published by Bailliere, Tindall & Co., King William St., Strand, London, England. Annual subscription, $3.00. There is no magazine published in this country that is exclusively devoted to analytical chemistry. The journal of the American Chemical Society, published by the Chemical Publishing Co., Easton, Pa., can also be recommended.

***

(307) Kindly give a method for the determination of gold and silver from ores, by the wet method.
E. G., Helena, Mont.

ANS.—There is no reliable and positively correct scheme for the wet determinations of gold and silver in ores. We would strongly recommend you to make fire assays, which are quicker and, if properly executed, more reliable than wet assays.

***

(308) Kindly give me the technical name and formula of Rochelle salt.
P. L. G., Matehuala, S. L. P., Mexico.

ANS.—Rochelle salt is sodium-potassium tartrate; its chemical formula is $NaKC_4H_4O_6, 4Aq$.

SCIENCE AND INDUSTRY

Vol. VII December, 1902 No. 12

BOILER TYPES—BELLEVILLE AND NICLAUSSE

WILLIAM BURLINGHAM

WATER-TUBE boilers are divided, broadly, into two types: first, those with tubes of small diameter, very light for the power developed, and capable of being used under heavy forced draft without leakage of tubes or other injury. To attain these advantages, facility of cleaning and examination is sacrificed to a certain extent. Such boilers are suitable for yachts and torpedo boats. The Thornycroft, a description of which was given in the August issue of this magazine, is a very successful boiler of this type.

Second, those with tubes of large diameter, thoroughly accessible, both outside and inside, for examination and cleaning, and with their internal steam and water passages so large as to render any obstruction due to dirt or grease, practically impossible. Such boilers are suitable for stationary use, large war vessels or any vessels or cruisers in which the maintenance of high power, for long periods of duration, is desirable.

There are three boilers of this type that are occupying the attention of the American and English engineers: the Belleville, Niclausse, and Babcock & Wilcox.

The subject of this article will be the Belleville and the Niclausse. The Belleville is the oldest French type and has been very extensively used in the British navy, but has yet to be tried, to any extent, in the United States. The accessories to this boiler are very numerous and make a considerable addition to the machinery of the ship.

The disadvantages of this boiler are as follows:

The extremely small amount of water necessitates an automatic feed-water regulator. Any failure of this regulator to work is attended with serious consequences, often causing the water to entirely disappear from the boiler. The resulting large variations in steam pressure necessitates a reducing valve between the boilers and engine, the boilers carrying steam at a pressure of from 50 to 100 pounds above that at the engine throttle. The slow circulation causes the tubes to wear out quickly, if there are any impurities in the water.

The system of feedwater circulation causes a large amount of priming, and even with the complicated arrangement of baffle plates, and a separator, this is still one of the troubles.

On the first French vessel using this type of boiler, there was as much as 10 per cent. of water at the high-pressure cylinders. This has been remedied to a great extent, in later years.

The great necessity for an absolutely sure-action feed-pump, led to the adoption of the Belleville feed pumps. The number of machines necessary

for the safe acting of this boiler necessitates a large number of repairs. The tubes have screw joints, making it very difficult to break a joint when a tube wears out. The average cost of repairs is considerably greater than with the old-type Scotch boiler.

The several advantages are not confined to this type of water-tube boiler

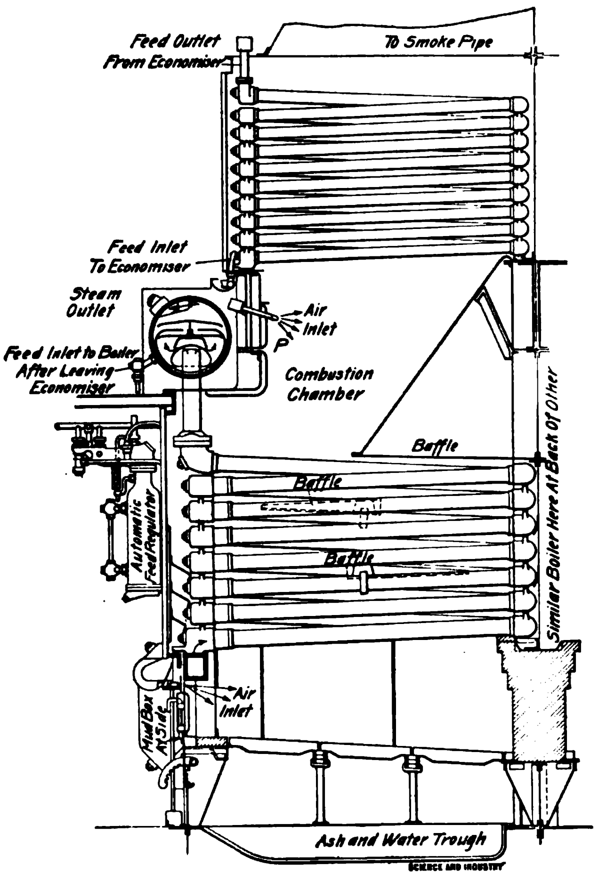


FIG. 1. BELLEVILLE BOILER

alone, but would apply to the principal ones of the large-tube type. They are as follows:

1. Less weight as compared with same power.

2. The ability to use high-pressure steam without the thick plates necessary in the Scotch boiler.

3. The parts are small and easily removed and replaced, without tearing up decks.

The later type of Belleville boiler is shown in Fig. 1. This shows an economizer above the generating tubes. The original boilers as installed on the "Powerful" class, were constructed without an economizer, consisting merely of the drums and generating tubes; but, as in all large-tube water-tubular boilers, it was impossible to use forced draft of any but the lowest pressure, the hot gases going directly to the smokestack despite the tile or steel baffle plates. The addition of the nest of economizer tubes afforded a space between these tubes and the steam-generating tubes that filled the office of a combustion chamber. The gases lost their speed in this chamber and became thoroughly intermingled before passing to the economizer, and there the last possible units of heat were extracted from the gases. This arrangement improved matters decidedly, but even now these boilers cannot be forced to anything like the amount that is possible with the Scotch boiler, or small-tube water-tubular.

The figure shows an elevation of the side section. The boiler consists essentially of a series of elements, side by side. Each element is made up of a series of straight, large diameter tubes, zig-zagged vertically over each other, and connected at the ends by malleable cast-iron boxes, with handholes in each front-end box.

In the first boilers fitted on the ships

of the British navy each element consisted of 20 straight tubes of $4\frac{1}{2}$ inches external diameter and about 7 feet 6 inches long. In the later one shown in Fig. 1, the number of generating tubes in each element was reduced to 14, and the remainder of the heating surface, made up by the economizer tubes, was used to heat the feedwater. The fire bars are short, 3 bars usually to the length of grate, situated from 22 to 26 inches below the lowest line of tubes.

As will be seen from the figure baffle plates of tile or steel are fitted in the nest of the tubes to deflect the impinging hot gases, in order that the entire surface of the tubes may receive the benefit of their heat. A steam drum at the front top and a water drum at the front bottom are connected to all the elements, and the tubes of the elements form one continuous passage, in each element, from the water drum to the steam drum. If the entire sectional area of the inlet of the tube was in connection with the water drum, it will be seen that the central elements would be apt to miss getting their fair share of water. In order to prevent this, the Belleville people reduced the inlet by bushings until it was of exactly the diameter to furnish each and every element with the requisite amount of water. The right diameter of hole was found by experiment, as follows: Small pipes with cocks outside were fitted in place and the cocks turned until the correct proportion of steam and water was discharged from them. Each element has two safety plugs of lead, one at the top and the other at the bottom.

A series of from 7 to 10 elements placed side by side constitute one boiler, and the flames making their way up between them generate the steam, which steam and hot water forces its way through the series of tubes in each element to the steam drum, from whence the steam is piped to the engine and the water deflected by baffle plates, drops to the bottom of the steam drum, joining with the feedwater, which is admitted to this drum through a small hole at considerable higher pressure than that in the boiler. It then flows through the return water tubes and sediment chamber or mud-box to the water drum. In order to prevent this comparatively cold water in the steam drum from interfering with the steam exit from the outlets of the elements, the outlet pipe is extended upwards until about 8 inches from the bottom of the steam drum. The tubes are, therefore, not of the "submerged" or "drowned" type.

As the free water reaches the mud-box, it passes through a non-return valve and then down and up in the box around a baffle plate, the comparatively large volume at the bottom of mud-box allowing the water a chance to settle and the sediment and lime to be deposited. The use of the abovementioned non-return valve is to prevent the water leaving the elements and ascending the return tubes when the ship is rolling, and, what is of more importance, it regulates the direction of flow of circulating water when steam is being raised. A peculiar feature of a Belleville boiler plant is the purifying of the feedwater before use by means of a box filled with quicklime into which a small stream of feedwater is admitted at a high pressure. This stirs up the lime and divides it into finely comminuted particles which are then pumped into the feedwater where the grease adheres to the particles of lime and when these particles reach the mud-box they settle to the bottom. This type of boiler, without economizer, was fitted into the ships of the "Powerful" class. With the economizer they were installed in the "Diadem" and her class. The admission of

sea-water pertains more or less to the marine, and does not come within the province of stationary work. It is enough to say that the use of sea-water as feed is very objectionable, because of the various salts deposited in the tubes causing loss of heat in transmission and burning out of the tubes. The casing of this boiler is an example of good design. It is composed of plates riveted together so as to form a number of expansion joints. There are a series of vertical angles, or tees, acting as stiffeners. The plates are united to these by curved ends and riveted, the ends thus affording the necessary means of expansion.

The upper part of the casing is lined with magnesia or asbestos, and the lower part, next the fire, with firebrick. The automatic feedwater mechanism is so arranged as to keep the water at about ½ to ⅝ glass. As there is considerable difference in pressure between the top and bottom connections of the water glass, it does not register the actual amount of water necessary to balance the statical pressure in the boiler. The use of this glass must be learned from experience and not judged from Scotch boiler practice.

From Mr. Oram, inspector of machinery, British navy, we have the record shown in the accompanying table of the evaporative trials of Belleville boilers with economizers.

In firing the furnaces of boilers of the Belleville type, it is absolutely necessary to have skilled stokers. With natural draft, the fire should be kept at a uniform thickness of from 4 to 5 inches to allow of the requisite amount of air through the fire. At the same time it must be of sufficient thickness to prevent its burning into holes and thereby admitting large volumes of cold air. All considerable variations of thickness must be avoided, and the rule that must be followed with any type of water-tube boiler is to "fire little but fire often."

As regards the air supply for complete combustion of the coal, experience has shown that the draft pressure at the base of the stack should be about as follows:

18 lb. coal per sq. ft. grate surface, .35 to .4 in. water
24 lb. coal per sq. ft. grate surface, .5 in. water
30 lb. coal per sq. ft. grate surface, .7 in. water
40 lb. coal per sq. ft. grate surface, .9 in. water
With the same height of stack and no accelerated draft.

By "inches of water" is meant the height of a column of water held up by the air pressure in the fireroom or ash-pit, and is determined from an instrument of the following description:

A bent **U** tube has one end open to atmospheric pressure and the other connected to the fireroom or ash-pit pressure. The difference between the heights of the water in the two legs of the **U** represent the "inches of water," and each inch represent an atmos-

Coal burned per square foot grate surface, pounds	18.5	24.5	31	37
Ratio heating surface to grate surface, generator	21	21	21	21
Ratio heating surface to grate surface, economizer	11.7	11.7	11.7	11.7
Ratio total heating surface to grate surface	32.7	32.7	32.7	32.7
Actual evaporation water into pounds of dry steam per pound coal	9.94	9.62	9.33	9.17
Equivalent evaporation from and at 212°	12	11.6	11.2	11.0
Steam produced in pounds per square foot grate surface	183.9	235.7	289.2	339.3
Temperature of feed, Fahrenheit	68°	68°	68°	68°
Steam pressure	205	215	220	230
Temperature of feed leaving economizer, Fahrenheit	226°	250°	300°	330°
Temperature at base of stack	394°	518°	650°	750°
Temperature in combustion chamber	860°	1,112°	1,300°	1,560°
Vacuum base stack, inches water	.46	.62	.8	1.12

Record of evaporative trials of Bellville boilers equipped with economizers.

pheric pressure of .036 of a pound or .576 ounce.

A comparison of the weights of the more important water-tube boilers and the ordinary cylindrical boiler follows:

Name Boiler	Weight Per Square Foot of Heating Surface	Floor Space ÷ Grate (Actual Space)	Steam Pressure	H. S. / G. S.	Sectional or Non-Sectional
Babcock & Wilcox	25–26	1.87	250	42	Sectional
Niclausse	28–30	1.5	250	42	Sectional
Belleville	38	1.61	250	31	Sectional
Dürr	26.5 Including Super Heater	1.61	218	42	Semi-Sectional
Thornycroft	18* / 12.5†	2.1	250	56	Non-Sectional
Normand	12.5†	2.2	210	47	Non-Sectional
Yarrow	12† / 20‡	2.	250	50 / 60	Non-Sectional
Cylindrical	73	2.12	210	33	Non-Sectional

*Monitor Arkansas includes air heaters.
†Torpedo boats.
‡Battleships. Large tubes. 1¾-inch diameter.
The weights given above are those for the boilers complete when in operation, but do not include uptakes. The space is represented by the projection of the boiler on the floor, from the extreme contour in the rear to the furnace doors.

Another boiler that is attracting considerable attention in the United States is that known as the Niclausse, manufactured by the Stirling Company, of Barberton, Ohio. At present these boilers are used on the United States ships Nevada, Maine, Georgia, Pennsylvania, and Colorado, besides two ships of 12,000 horsepower of the Great Northern Steamship Company. It behooves us, therefore, to become familiar with this type also. Naturally boilers of these new types are tried in the marine service long before they are used in stationary work, but eventually they all drift our way.

The Niclausse boiler is a French invention and has been and is still used very extensively in France.

Fig. 2 gives a general idea of this boiler, with a detail of the peculiar manner in which the tubes are fitted up. The boiler consists essentially of a series of double tubes, inclined toward the back end of the furnace. There is a double row of from eight to ten double tubes in a vertical line over each other, all connected to a common header. Eight or ten sets of these elements, side by side, constitute the boiler.

The double tube consists of a large tube containing a smaller one as shown, each tube opening into a separate chamber in the header. The connections of the tubes are so arranged that the water coming down the header chamber *A* flows down the inner tube and up the annular space inside the outer tube, to the steam chamber *B* of the header when heated by the hot gases from the furnace. As each vertical row of tubes discharges into a separate header, the steam and water currents of each series are independent of each other.

This series of headers, placed side by side, enter a common steam drum. The drum is fitted with a diaphragm and means for keeping the descending currents of water and the ascending currents of hot water and steam separate. At the back end of the boiler there is a plate with holes supporting the loose ends of the outer tubes.

The great peculiarity of this boiler is its very ingenious arrangement of tube

ends. The tubes fitted with coned metal points are kept in position by outside dogs. These keep the coned surfaces of the tubes in contact with the coned surfaces of the headers. A tube can be withdrawn and replaced in a few moments, and experience has proven the points to be steam tight and enduring, with the advantage that the entire boiler can be examined from the front and all repairs to tubes, etc. made from the same place. There is a pipe connecting the bottom of all the headers for blowing out purposes. The inclination of the tubes, however, forbids an entire clearance of water, as there will always be some left in the back ends of the lower tubes. This lower row is made of heavier gauge than the others to obviate as much as possible the trouble due to chopping or sagging from the intense heat. The tubes of this boiler being free at one end, there is no trouble from expansion, and consequently more freedom from dangers of leakage.

The circulation of the feedwater in the boiler depends entirely on the difference in weight of the different columns in the water leg. The higher the boiler the better the circulation. Any of these boilers, however, have a good circulation.

The economy of the boiler is not great at high rates of combustion. If it were possible to have a combustion chamber the economy would doubtless be much improved.

The inner tube is not supported and may in time come to rest on the inside of the evaporating tube, but this is not necessarily much of an objection.

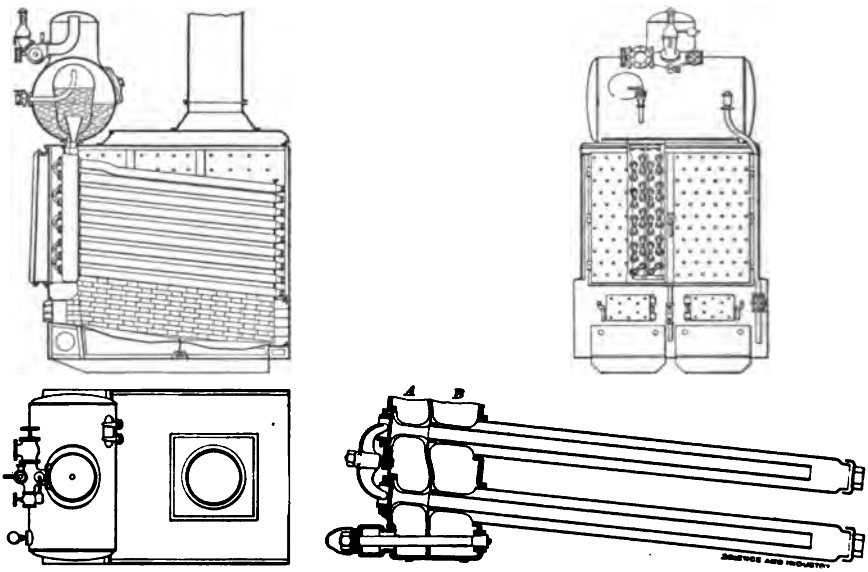


Fig. 2. Niclausse Boiler

The floor space occupied, for a given heating surface, is reduced to a minimum. The tubes are slightly inclined, but the ends of the boiler are vertical.

The boiler does not work as regularly as could be desired, because of the small amount of water contained therein. Yet it does not need the auxiliaries that are used with Belleville type, the auxiliaries necessary being

the same as those used with the Scotch boiler.

The Niclausse boiler is very easily and quickly repaired. The claims of the inventor are as follows: Advantages of small weight and good utilization of the coal, in addition to those reasons already given.

From the inventor, we have the best method of taking care of the boilers. They are, in a general way, applicable to almost any type of water-tube boiler, and are as follows:

According to the quality of the water used in the boiler and the amount of work done, the inspections of the tubes will be more or less frequent. When first used, the lower row of tubes should be examined frequently, to determine when and how often the boiler should be cleaned.

The part of the collectors that is most liable to become dirty with use is the upper part. Cases have occurred where the deposits in the top of the collectors have stopped the circulation, and tubes have been burned out.

The boiler must not be emptied except when about to be cleaned, as the deposits would otherwise become hard and difficult to remove. These deposits will be found most generally in the circulating tubes to the exclusion of the evaporating tubes.

The blows should be used once a day; the cocks are frequently stopped and must often be examined.

To clean a tube, it is necessary to remove the safety bar and unscrew the inner tube. These tubes contain the deposits to be removed either by washing or by a metallic sponge. A special key is furnished to prevent the turning of the outside tube when the inner one is unscrewed. If the evaporating tube needs cleaning it can be done either in the boiler, or it can be drawn out. Care must be taken that the coned seats are free from grease before the joint is made. In general, all the tubes of a boiler are cleaned at the same time, commencing with the bottom row in removing, and the top row in replacing them. While the tubes are out of the boilers the collectors are swept and cleaned. The tubes are cleaned on the outside by a steam sweep that is placed in the openings between the collectors. The tubes are swept in horizontal rows beginning at the top of the boiler.

The other parts of the boiler that require examination from time to time are the feedpipe and the drum fittings. Boxes to collect the deposits from the feedwater are placed in the drum and must be cleaned frequently.

The feedwater is regulated entirely by a check-valve placed at the boiler. Any sudden increase in pressure is stopped by the use of more feedwater.

In case of leaks, the nuts on the safety bars should not be screwed up. This may cause breaking of the joint and explosion of the boiler. All leaks are the result of dirt in the joints, and no leak can be stopped without remaking the joint. If the joints are properly made in the first place, no leaks should appear during the working of the boiler.

During stops, the ash-pit doors are closed, but neither the doors to the grate nor those to the tubes are opened. More especially, if the feedwater falls below the bottom of the glass, should these doors be closed. In this case, the fires must be drawn at once unless the cause of the lack of water is at once discoverable.

When the boilers are no longer required, the blows are used and the water level is raised to the top of the glass. The fires must be pushed to the back of the grate, or even drawn. In this boiler, the sudden change of

temperature has no bad effects. When a boiler is not to be used for some time, it is cleaned and then completely filled with water.

An extract from a circular of the French Minister of Marine, regarding the use of lime in feedwater, may be of interest in this connection:

"It is best to add lime to the feedwater after leaving the filter, as for example in the feed-tank, care should be taken to prevent the lime from settling to the bottom of these tanks. It is best that the lime should go to the boiler and mix with the water in the boiler and there be dissolved.

"In certain cases, it may be advantageous to introduce the lime directly into the boilers. In this way it would not pass through the feed-pumps.

"As to the amount of lime to use, there is an advantage in not exaggerating it, and for this it is essential to determine at least once in four hours the acid or basic condition of the water in the boiler by litmus paper, or in some other simple way. In general, the proper amount of lime to be delivered is about 1.7 pounds per ton of coal in the bunkers. But it is to be understood that the amount to be used will vary, so that the water in the boilers will never have any trace of acidity, but it will give a good basic reaction."

The accompanying tables show a comparison of a Belleville and Niclausse plant on sister ships of same speed and power.

The data for these two types are necessarily taken from marine practice as there is no available material at present from stationary work. The boilers, if built for stationary work, as they will be eventually, will no doubt be constructed a small per cent. heavier, but the general principles of their design and working will remain the same.

	Belleville	Niclausse
Number of firerooms	3	3
Number of boilers	24	20
Furnaces per boiler	1	1
Length of grate	4′ 7″	6′ 8″
Width of grate	7′ 0″	6′
Total G. S. square feet	755.2	782.8
Total H. S. square feet	21,594	23,338
Ratio H. S. to G. S.	28.6	29.8
Outside diameter of tubes	3.23″	3.23″
Inside diameter of tubes	2.86″ & 2.60″	2.97″
Length of tubes		
Diam. circulating tubes	6′ 4″	5′ 8¼″
Number of tubes in vertical row		1 3/16″
Volume of water in tons	9	9
Volume of steam, cubic	16.2	46.2
feet	784	830
Boiler pressure	242	214
Pressure at engines	170	170

The weights of these boiler plants are as follows:

	Belleville	Niclausse
Boilers proper		148.5
Uptakes	273.3	56
Accessories		6.6
Grates and fittings		18.3
Tools and span parts	8.1	7.6
Feed pumps	11.4	5.2
Tanks	8.0	4.0
Smokestacks	23.5	19.8
Floor plates and ladders	9.0	9.0
Fireroom ventilators	9.0	9.0
Air compressor	2.5	
Separator	5.2	
Water in boilers	16.0	53.0
Total, all firerooms	365.0	335.0
Total, all machinery	801.0	760.0
All in tons, 2,240 lb.		

In this comparison the Niclausse for the same power shows up 40 tons lighter.

In the next article on boiler types, we will take up the design and construction of the well-known Babcock & Wilcox boiler, probably the best known water-tube boiler in stationary work in the world.

The Babcock & Wilcox people have lately entered the marine field with a type of boiler that is similar to their land boiler, but lighter and more strongly constructed.

FEEDWATER HEATERS

Used in Connection With Economizers

JOSEPH E. LEWIS, S. B.

IT is a mistake to assume that the fuel economizer is a substitute for the feedwater heater; but this mistake is often made, and we are occasionally told by some one building a new power plant, that he will not require feedwater heaters because he is going to use economizers.

Now, the use of economizers does not obviate the necessity of using feedwater heaters; on the contrary it makes some sort of a heater almost necessary, because cold water should never be admitted to an economizer. Every one is familiar with the "sweating" of pipes carrying cold water. This same action takes place in the case of the economizer if the entering water has a temperature less than 100° F. The moisture thus deposited upon the outside of the pipes acts as a medium for collecting soot and ash, which are thus converted into a gummy, adhering substance very hard to remove from the pipes. When the pipes are dry the soot and ash collect in the form of a fine dust which is readily removed. The importance of this point appears when it is remembered that the efficiency of the economizer is greatly impaired unless the pipes are kept clean and free from collections of this sort. On this account provision is always made for cleaning, which is readily accomplished if the pipes are supplied with hot water so as to always be dry.

It is essential, therefore, to have a preliminary heater of sufficient capacity to heat the water to at least 100° F. This result may be obtained in the usual form of primary heater placed between the low-pressure cylinder and the condenser so as to heat the water by means of the exhaust from the main engine. The temperature thus obtained in the feedwater will depend upon the temperature of the steam due to the vacuum carried. In a properly designed heater of suitable capacity the water may be brought to within 5 degrees of the temperature of the steam. The temperature of the steam due to a vacuum of 28 inches is 100° F.; 27 inches, 114° F.; 26½ inches, 120° F.; 26 inches, 125° F.; 25½ inches, 129° F.; 25 inches, 133° F.; 24 inches, 141° F.; 23 inches, 146° F.; 22 inches, 152° F.; 21 inches, 156° F.; 20 inches, 161° F.; 19 inches, 165° F.; 18 inches, 169° F.; 17 inches, 173° F.; 16 inches, 176° F.; and 15 inches, 179° F. Thus, with 26 inches of vacuum, a primary heater should deliver the water to the economizer at about 120° F., which will prevent any difficulty from "sweating" of the economizer pipes. It is, therefore, clear that the primary or vacuum heater should not be omitted in a condensing plant using economizers.

It may now properly be inquired whether there is any further advantage to be gained by using an auxiliary or secondary heater to further heat the feedwater before admitting it to the economizer. Where economizers are not used it is a well grounded practice to install a primary heater in the exhaust pipe of each condensing engine, and to install an auxiliary heater at some convenient point, usually in the boiler room, to utilize the exhaust at atmospheric pressure from boiler feed-pumps, condenser and receiver pumps, exciter engines, etc., in further heating the feedwater before putting it into the boiler. The utility of an auxiliary

under these conditions cannot be questioned; but what about its use where economizers are installed?

In case circumstances render it inadvisable to use a primary heater, an auxiliary should undoubtedly be used to take its place, to avoid cold water, but in condensing plants it would rarely happen that primaries could not be used advantageously; what advantage will there be, then, in using an auxiliary also?

Theoretically considered, there would appear to be some advantage gained from the fact that the hotter the water is upon entering the economizer the hotter it will be upon leaving, and therefore, the hotter upon entering the boiler, which is, of course, the result desired It does not follow, however, that because an additional 75 degrees is added to the water before entering the economizer that this same increase will appear in the final temperature. The final temperature will be increased, it is true, but by a less amount. We might reasonably look for an increase of 20 or 30 degrees, but probably not more.

A further advantage may result from the fact that less heat is abstracted from the flue gases so that the natural draft of the chimney is reduced less where the auxiliary heater is used than when it is not. This may, in some cases, become an important consideration; in others, it would not figure at all, as for example, where mechanical draft was employed.

The most practical way to answer a question of this kind, however, is to cite the best recent practice upon the point. The limits of this article will not allow anything like an exhaustive study of modern practice in feed-water heating, but we may at least select one typical plant for discussion. Of course practice varies upon this point as upon all others, but it is fair to suppose that the best practice will be found in the design of the new Kings' Bridge Power House of the Third Avenue Railway Company, in New York City, which is now being built by Messrs. Westinghouse, Church, Kerr & Company. The station, when completed, will probably be the largest power house in the world, and will represent the best and most up-to-date engineering practice. A very thorough and careful study of the feedwater problem, which did not stop short of a minute analysis of every phase of the question, has resulted in the use of both primary and auxiliary heaters together with economizers, so that it would be difficult to find a more cogent argument in favor of this practice, especially when the world-wide reputation of the engineers is considered.

The heaters to be employed in this plant are now under construction. They are of the copper-coil type, and are the largest heaters of this type ever built. The primary heaters will be mounted on the 54-inch exhaust main upon the induction system, instead of being separately located in the exhaust of each individual engine. The auxiliary is conveniently located to receive the exhaust from feed-pumps, circulating engines, dry vacuum pump, lighting engine, stoker engines, and exciter engines. The amount of surface in the primaries is calculated sufficient to raise the temperature of the feed-water to about 110° F. at 26 inches vacuum. The auxiliaries are designed to further raise the temperature to about 175° F., which will be about the average temperature at which it will enter the economizers. At light loads these temperatures will be 120° F. and 210° F. respectively, and at full load they will fall off so that the temperature upon entering the economizer will be only about 150° F.

In the case of the primaries it would have been possible to have provided surface enough to heat the water to within 5 degrees of the exhaust-steam temperature, but this was considered undesirable because the increase in cost would more than offset the advantage gained. That is to say, as the temperature of the water in the heater approaches that of the steam the heat transfer becomes slower, so that the amount of surface required increases enormously. To illustrate, with 26 inches vacuum it was determined that each primary should have 1,180 square feet of surface to heat the water from 40° F. to 110° F., or within 15 degrees of the temperature of the steam, at the average load; while it would require about 1,650 square feet of surface to obtain 120° F. That is to say, the last 10 degrees is secured at the expense of 470 square feet of surface, or about two-fifths of the total surface used to obtain the first 70 degrees. For this reason it was thought advisable not to try for too high a temperature in the primaries. This same 10 degrees, from 110 degrees to 120 degrees, can be obtained in the auxiliary, using steam at atmospheric pressure and 212° F., with less than 100 square feet, due to the more rapid transfer of heat when the temperature difference between water and steam is greater. It was, therefore, economy to let as much of the heating as possible be done in the auxiliary; but it could not all be done there owing to the limited supply of auxiliary steam, which, taking the water at 110° F., is sufficient to raise it to 175° F. at average load. It was not thought advisable to try for a temperature much in excess of 200° F. in the auxiliary, for the same reason that it was not desirable to try for more than 110 degrees in the primaries. That is to say, anything above 200 degrees can be obtained more economically in the economizer.

We give below a table recording the average temperatures obtained in a number of representative plants. The temperature upon entering the economizer, and upon leaving the same, is given in each case. An examination of this table will show clearly the gain in final temperature due to heating the water before entering the economizer:

Name of Company	Location	Temperature	
		Entering	Leaving
Curtis Publishing Co.,	Philadelphia, Pa.	38	193
Brooklyn City Railway Co.,	Brooklyn, N. Y.	50	170
So. Chicago City Railway Co.,	Chicago, Ill.	89	221
Toronto Railroad Co.,	Toronto, Canada.	101	237
Berkshire Manufacturing Co.,	Adams, Mass.	102	195
Union Railway Co.,	Providence, R. I.	110	210
Lancaster Mills,	Clinton, Mass.	120	240
New York Mills,	Utica, N. Y.	130	240
Pacific Mills,	Lawrence, Mass.	140	285
Solvay Process Co.,	Syracuse, N. Y.	163	302
Cheney Bros.,	South Manchester, Conn.	178	288

THE AMATEUR'S LABORATORY—III

R. G. GRISWOLD

THE WHEATSTONE BRIDGE AND THE MEASUREMENT OF RESISTANCE

EVERY conductor of electricity offers some resistance to the passage of the current. This resistance may be measured by several methods, that known as the Wheatstone bridge

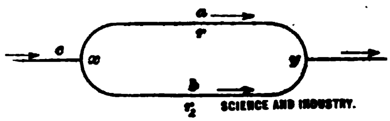


FIG. 1

method being the simplest and perhaps the one most generally used. Its range is theoretically almost unlimited, but as the value of the resistance increases the very slight errors of adjustment in the standard coils are multiplied until in the case of resistances of hundreds of thousands of ohms, the nearest approach to accuracy that we may attain is within percentages varying from one to four. Bridges of this type are generally constructed with coils of platinum or platinum-silver wire, the temperature coefficient of which is very low, and would be very difficult for the amateur to construct and adjust. One form of the bridge, however, known as the "slide-wire" type, is quite accurate enough for ordinary work and will be described in this article.

The principle upon which the construction of this bridge is based is a direct application of the law of multiple circuits. If we divide a circuit into two branches, a and b, Fig. 1, a current flowing in conductor c will divide at x, a certain portion passing over a and another portion over b, again uniting at y. The strength of the current flowing in either of these branches depends upon their respective conductivities, which term may be expressed as the reciprocal of the resistance, or $\frac{1}{R}$. Thus, if the resistance of a is r_1 and that of b is r_2, their respective conductivities are $\frac{1}{r_1}$ and $\frac{1}{r_2}$. It is evident, therefore, that if the resistances of these two branches are equal, the current flowing in each will be equal, and that any increase of resistance in either branch will cause less current to flow through it, while a decrease of resistance will have the opposite effect.

Now, if we connect the two conductors by a wire with a galvanometer in circuit, as shown in Fig. 2, at such points m and n as have the same potential, no current will flow over the wire and the galvanometer will show no deflection. But if one of the points m or n is moved one way or the other, a difference in potential will result and a current will flow through the galvanometer, causing a deflection. When no deflection is shown, it is obvious that the resistance from x to m must bear the same ratio to the total resistance of a as that from x to n does to

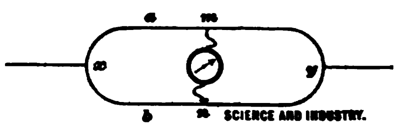


FIG. 2

that of b. Therefore, we have the proportion,

$$xm : a :: xn : b,$$

from which it follows that the proportion

$$my : a :: ny : b$$

also holds good. Transposing, we have,

$$xm : xn :: a : b;$$
$$my : ny :: a : b.$$
$$\therefore xm : xn :: my : ny,$$

or the resistance of xm : resistance of xn :: resistance of my : resistance of ny. This proportion enables the value of one of the resistances to be calculated if the other three are known.

The theory of the bridge can now be easily understood from the diagram in Fig. 3. It will be noticed that this diagram is the same in principle as that of Fig. 2, neglecting the sections m and n for the present. The sections *1–2*, *2–3*, *3–4*, and *4–1* are called the arms of the bridge and are designated as a, x, c, and b, respectively, for convenience. The resistances of the arms

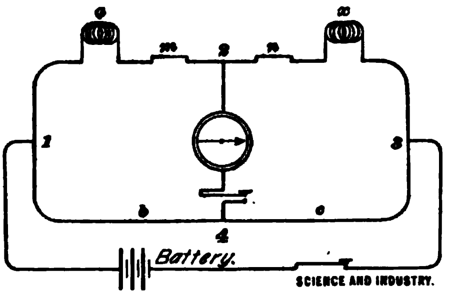


FIG. 3

a, b, and c are variable and known. The resistance x is unknown and is the one to be determined.

Let us suppose that the arms b and c are formed of one piece of wire and that the point *4*, which can be moved along the wire, determines the division point between the two arms. It follows from the proportion stated above that if the resistance of a is equal to x the point *4* will be in the middle of the wire, assuming that the wire is of uniform cross-section, and the galvanometer shows no deflection. Now, if the value of a is reduced, and that of x remains the same, the point *4* must be moved nearer to *1* in order that the proportion above stated may still remain true, and that the points *2* and *4* shall have the same potential. The resistance of this wire will vary as its length and the resistances of the arms b and c will bear the same ratio as the lengths intercepted between the points *1* and *4*, and *4* and *3*.

A further study of the proportion $a : x :: b : c$ at this point will prove that the sensitiveness of the bridge is greatest when the readings are taken from the central portions of the wire, and that the greatest accuracy is attained when the resistance of a is equal to x. Solving for x, we have,

$$a : x :: b : c$$
$$ac = xb$$
$$x = a\frac{c}{b}.$$

The scale for reading the position of point *4* is generally divided into 1,000 parts. The multiplying value of the fraction $\frac{c}{b}$ when point 4 is on the middle division of the scale is $\frac{500}{500} = 1$. Moving it one division to the left the value of the fraction is $\frac{501}{499}$; two divisions, $\frac{502}{498}$; three divisions, $\frac{503}{497}$, which shows that the value of the fraction varies little with each movement of one division in this portion of the scale. But as the point *4* approaches the ends, we find that the value of the fraction increases rapidly. Thus, at 250 it is $\frac{750}{250} = 3$; at 200 it is $\frac{800}{200} = 4$; at 100 it is $\frac{900}{100} = 9$; at 50 it is $\frac{950}{50} = 19$; at 25 it is $\frac{975}{25} = 39$, and at 976, one division more, it is $\frac{976}{24} = 40.7$. If point *4* is moved in the opposite direction the value of the fraction decreases at the same rate.

In practice, it will be found that with a very sensitive galvanometer, like that described in the second article of this series, a very slight movement of the point *4* when near the middle of the scale will give a sensible deflection, but when it nears either extremity the multiplying value of the fraction increases so rapidly that it is extremely difficult to secure an accurate adjustment.

When $b = c$, the value of $a = x$. Should the value of x be greater or less than the value of any resistance a used for comparison, then b and c can be arranged to multiply or divide the resistance value of c. For example:

Let $a = 100$;
$b = 100$;
$c = 900$.

Then, $x = 100 \times \frac{900}{100} = 900.$

Again, let
$a = 100$;
$b = 900$;
$c = 100$.

Then, $x = 100 \times \frac{100}{900} = 11.11.$

In order that the resistances of b and c should be in proportion to the lengths of wire between the sliding contact and the ends, it is necessary that the cross-section of the wire should be uniform throughout its length.

The bridge is illustrated in Fig. 4. The base is made of some well-seasoned hard wood, the pores of which have been thoroughly filled with shellac varnish. The wire is No. 24 hard drawn German silver. The inside edges of the anchors for the ends of the wire should be exactly one meter apart, which is practically 39.37 inches. After the anchors are firmly secured to the base at the proper distance apart, one end of the wire is soldered to its anchor, a shallow groove being filed in the top to receive it. Then the wire is drawn very taut and the other end soldered. The brass strips are ½ inch wide and $\frac{1}{16}$ inch thick. Where they meet at right angles the two pieces are mitered and soldered. The binding posts are made as directed in the first article. Numbers *1* and *2* are for the battery wires; *3* and *4* and cups *f* are for the insertion of resistance coils or instruments. The cups are made by drilling slight depressions in the ends of the bars with a No. 30 drill, 1 inch apart.

The slide illustrated at *c* is made from a piece of $\frac{1}{32}$-inch hard sheet brass. A small wooden knob is fast-

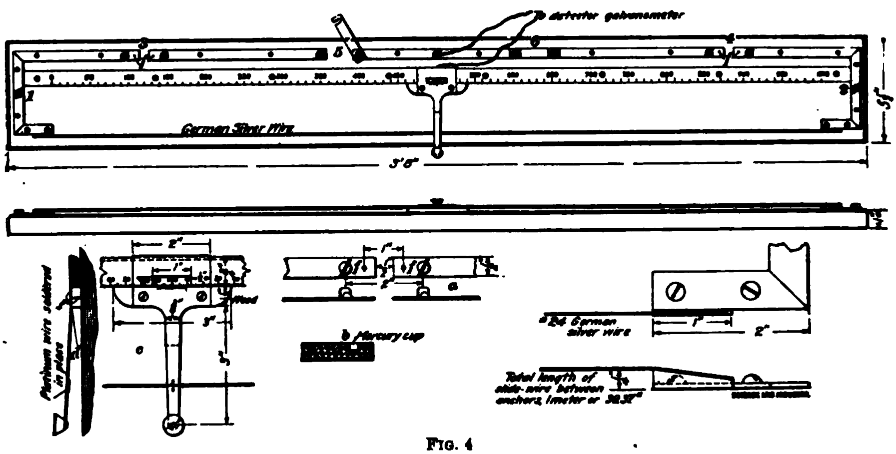


FIG. 4

ened to the end. The other end is bent over and under so as to grasp the beveled edge of the scale. A small piece of wood *d* is extended in front to prevent the pressure on the spring lifting the vernier off the scale. The portion bent under should be split for about $\frac{1}{2}$ inch from each edge in the bend, the tongues thus formed being sprung inwards so as to make the slide work smoothly and keep the vernier close to the scale. The contact point should be made of a piece of platinum wire sharpened to an edge and soldered in place as shown. If platinum cannot be secured, a piece of the German-silver wire used on the bridge will answer. Use a very small piece of solder, as platinum readily forms an alloy with it.

The vernier, shown in Fig. 5, is made by cutting a slot 1 in. $\times$ $\frac{1}{4}$ in. in the brass, one edge of which corresponds with the edge of the scale. The scale is divided into millimeters, and the vernier, being a double one, enables readings to be taken in either direction. The zero division is on the center line, and a distance equal to 9 millimeters is laid off on either side of the zero line and divided into ten equal divisions.

This vernier will permit readings of $\frac{1}{10}$ millimeter to be made. When the zero division on the slide coincides with a division on the scale, the number of the scale division determines the reading. But should the zero division fall between two scale divisions, the fractional part of a millimeter is determined by reading along the vernier until two divisions are found that exactly coincide. The number of the vernier division from the zero indicates the number of tenths of a millimeter that the zero division has moved beyond a scale division, the reading being made in the same direction as that on the scale.

The scale may be made either of a piece of light-colored wood, or divided on a piece of bristol board and glued to a strip of wood. The exact dividing of this scale is not difficult. Secure a scale divided into millimeters and place it end to end with the scale to be divided. Then with a beam compass set off the divisions on the cardboard with drawing ink and in very fine lines, making the fifth divisions $1\frac{1}{2}$ times the length, and the tenth divisions twice the length, of the others, which should be about $\frac{1}{16}$ inch.

When the scale is finished it must be attached to the base in such a position that when the zero division of the vernier coincides with either the zero or

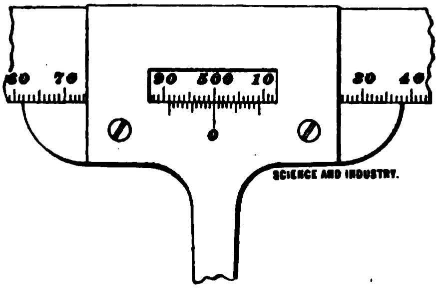


Fig. 5

1,000th division of the scale, the small contact point will be exactly in line with the inside edge of the anchors. The scale divisions should be numbered from left to right on every tenth division.

To use the bridge it should be connected up in the manner indicated in Fig. 6. Always close the battery circuit first and then that of the galvanometer by pressing the small slide knob. Move the slide along to such a position that the galvanometer shows no deflection when its key is depressed. Then take the reading which gives the value of b, and by subtracting it from 1,000 the value of c can be obtained. By inserting these values in the formula given above, the value of the resistance x can be calculated.

It will be necessary for the amateur to provide himself with a set of standards with which unknown resistances may be compared. The standard ohm

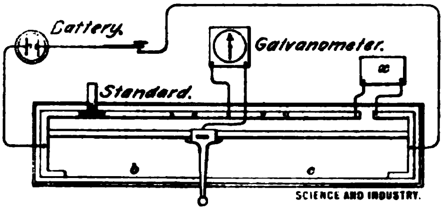


FIG. 6

as adopted by the International Congress of Electricians, held at Chicago, August 21, 1893, is represented by the resistance offered to an unvarying electric current by a column of mercury at a temperature of melting ice, 14.4521 grams in mass, of a constant cross-sectional area, and of the length 106.3 centimeters.

As the construction of this standard is practically impossible for the amateur, recourse must be had in the adoption of some material, the resistance of which has been compared with the above standard and accurately determined. Should he be fortunate enough to have access to a set of standards, it will be very easy for him to construct a set from these. But if not, a very satisfactory set can be made from pure copper wire, since its composition is fairly constant and its resistance per foot is given in the copper-wire table of the American Institute of Electrical Engineers. Taking the conductivity of pure copper as 100, that of commercial copper varies from 96 to 102 per cent. of the standard, but for our purpose this will make little difference, as the standards will be exact multiples or submultiples of each other, regardless of slight variations from the standard ohm.

A piece of No. 30 B. & S. gauge copper wire, 9.707 feet, or 9 feet 8.48 inches in length, has a resistance of 1 ohm at 20° C., or 68° F. Straighten a piece of No. 30 double cotton-covered magnet wire of this length. Wrap it on a spool like that shown in Fig. 7. Bend the wire exactly in the middle and wrap it on double so that the two ends will come off together. Fasten them with a thread and boil the whole in paraffin until all air bubbles cease to be given off. This is known as the non-inductive method of winding and is used wherever magnetic instruments are employed in the immediate neighborhood, as it has no magnetic effect, the field due to the current flowing in one direction being exactly neutralized by that caused by the same current flowing in the opposite direction. Using this coil as the standard, construct a similar one of finer wire for 10 ohms, one for 100 and one for 1,000 ohms.

In comparing the new coils with the standard better connection is made by putting the ends of the wires in the mercury cups, as shown in Fig. 7. These cups should be prepared by cleaning the inside with a drop of dilute nitric acid, then placing in each a drop of mercuric nitrate and a small globule of mercury. This treatment will cause the mercury to amalgamate with the copper and preserve a good contact. The ends of the resistance-

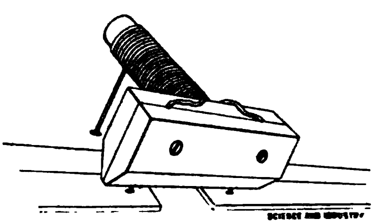


FIG. 7

coil wires should be treated in the same manner.

It is not supposed that these standards will be true in value, but they will be sufficiently accurate, if care has been

exercised in their construction, for ordinary purposes. They should be exact multiples of each other. Use the 10-ohm coil for calibrating the 100-ohm coil and the 100 ohm for the 1,000-ohm coil. They may be adjusted by cutting off small portions from the ends until perfect balance is secured. The position of the slide is calculated in this instance and set, the coils being adjusted until the galvanometer shows no deflection.

The two yokes *5* and *6*, Fig. 4, are provided to close the gaps in the brass strips. These gaps are for the insertion of the known and unknown resistances when greater delicacy is required in measurement. Gaps *3* and *4* are then bridged by coils having a resistance equal to a certain multiple of the resistance of the slide wire. This has the effect of lengthening the slide wire, and the battery leads are then connected to the bar between points *5*, and *6* and and *4*. The use of this method will be treated in a later article.

THE POSSIBILITIES OF THE STEAM AND GAS TURBINE

GEORGE E. WALSH

THE fact that the steam turbine is slowly displacing the old reciprocating engine in many lines of power manufacturing is sufficient evidence that the student and practical engineer must become as intimately acquainted with all that is being done to improve and develop this form of engine as circumstances will permit. So general has the demand for steam turbines become in this country that every part of the complete machine is now being made here, with the exception of the turbine wheel itself, which is still brought over from Europe, but within a short time even the turbine wheels will be of American manufacture.

The improvements being made upon the two distinct types of turbine engines now in use are quite important, and they show that the machine is still in its evolutionary period of growth. At present it is the simplest and least expensive of steam engines, but in its employment for operating electrical generators this cost is considerably added to because of the expense of building the electrical connections to make the plant complete. But outside of the question of the relative cost of the engine or the engine with its electrical generator, the question of greater efficiency according to the load to be carried, easily places the turbine first among steam engines. In designing and operating the modern turbine engine, this fact is constantly kept in the foreground, and the load efficiency of the machine is determined by the number and design of the nozzles.

There are two types of the turbine made and employed, and both are successful. The first will not be considered here so much as the second, for the reason that the latter is receiving the most attention from engineers. The first type is the earlier of the two, and it is formed on the principle of steam passing into the turbine case and working against the buckets of a moving turbine wheel, and then passing on to a second wheel of similar construction, progressing gradually from the second to the third, and so on to the end. This type of turbine has been developed to a point of efficiency where little further improvement seems possible at present; but the second type is capable of an infinite amount of exper-

iment and evolution which cannot now be measured.

The steam in this turbine is carried to the wheel case after it has been completely expanded in the different nozzles arranged for its reception, and not in the wheel chamber itself as it passes from one wheel to another. Consequently, it will be seen that the design of the nozzles must determine the actual efficiency of the engine. The sets of nozzles represent the most important part of the engine from the standpoint of the designer. One of these nozzles will deliver the steam at the highest possible pressure, and another at ordinary atmospheric pressure, and so on through all the varying degrees.

Each nozzle is designed to take the steam at a given pressure, and then expand it down to a required lower pressure. With a great variety of nozzles we have then the power to use only so much steam as may be required to carry a given load. The designer of the nozzles is supposed to make these, so that it can easily be calculated how many are needed to carry a light or heavy load. A turbine fully equipped with a great variety of nozzles can thus do with equal facility a light or heavy work without loss of much power. Only the proper nozzles are put in use to obtain a given working efficiency. It is because of this simple arrangement that the turbine of this type maintains a constant efficiency for a wide range in load. This is one of its features which needs particular emphasizing at this stage of its development, and one which will continue to impress the engineer, who is careful about utilizing all the power of his plant at the least possible expense.

The nozzles of the turbines which deliver the steam and expand it to the required pressure are simple brass tubes with taper holes reamed in them, and with the ends beveled off so that they just clear the buckets of the turbine wheel. The steam comes from the main pipe or chamber into these nozzles, and stop valves are arranged for opening and closing them. When it is desired to check the speed, and bring it down to carry a much lighter load, the nozzles with the heavy steam pressure are shut off, and to make the slowing down more rapid and effective, an air valve is opened to admit outside air to the condenser. This checks the speed quickly and smoothly, and permits the changing of the load without friction or much loss of energy.

The designing of the nozzles must be determined beforehand by the conditions and needs of the plant. Where the range of load carried does not vary much, the designing is very simple; but the greater variety of power needed the greater must be the use of specially designed nozzles. This type of turbine has naturally appealed with greater force to those operating plants where the range in load is constantly shifting and changing, and where efficiency must be measured to a large extent by the relative rapidity obtained in changing the load. In plants where a continuous load of a given figure is maintained day after day, this form of turbine appeals less persuasively, and the change from the old reciprocating engine to the turbine is less likely to be made at once.

In the second type of turbine engines there is no disadvantage from superheating, for the high temperature cannot cause trouble from expansion of the different turbine parts, as may be the case in the first type, where the steam is delivered direct to the wheel case and expanded there. The steam does not change form at all after it leaves the nozzle. All the expansion

is accomplished in the nozzle, and the delivery to the wheel parts is simple and at a given pressure. Superheated temperatures in the first type of turbine come in direct contact with the moving parts of the wheel, and these sliding parts must be more or less affected thereby. So wonderfully simple and effective is the second type of turbine that its use is rapidly becoming general for a great variety of plants.

Tests are being made and tables prepared, to show the exact size and shape of the nozzles required for certain loads. These tests have been made with superheated steam and with saturated steam. As the power and efficiency of the turbine depends upon the number of nozzles in action, it is evident that full sets of a dozen should be supplied for engines that are expected to vary their load considerably in the course of the day. For ordinary uses half a dozen is sufficient, and these will vary the load within the working range of most plants. The nozzles are controlled and operated by means of a hand wheel attached to each one, and their full capacity is thrown into active operation the moment the wheel is thrown open. The steam from each nozzle performs an exact working duty, and whether in action singly or together the same function is performed. The operator is thus able to vary the load of his engine with an economy of labor and power that is quite remarkable. If the indicated horsepower required for performing a certain work is determined beforehand, the operator can change his machine easily and steadily so that there will be a large saving in steam.

The turbine engine has been employed, so far, more extensively in operating electrical generators and high-pressure centrifugal pumps than for any other form of operating plant. Both types of turbines are used in this work. Where there is little trouble with superheated steam, and a continuous load carried by the engine, the first type still finds more general demand. It has some points of recommendation which make it popular. It is comparatively simple in design, and is inexpensive in construction. The wheels for both types have been made after years of careful experiment, and new improvements are being tried. The danger of a breakdown is for instance guarded against so far as possible; but as such accidents may happen in every plant, provision is made so that the weakest part of the wheels is placed where it can readily be repaired. This weak point is purposely placed just within the inner end of the vanes. A shallow groove is cut into the wheel. In case of any accident the break would therefore occur at this point, and the parts broken off would be light and cause comparatively little damage. The design of the turbine wheel is the result of the closest mathematical calculation and test. The hub of the wheel is thick steel, and very strong, and it tapers toward the buckets very gradually, so that the power exerted against it can never cause a break near the center. The stiffness of the wheel makes the strength uniform throughout.

The buckets of the wheel are separate pieces from the wheel itself, and they are carefully dovetailed into the rim by the most approved methods. The flanges of these buckets present a uniform appearance, and they are so arranged that should one be broken off it could be replaced in a short time. As a result of this, the machine is rarely placed out of work for any great length of time by accidents. The shafts of the turbine wheel are fitted so carefully in the hub that the wheel revolves

with great rapidity without causing any material vibration.

The rapid development and popularity of the steam turbine having been demonstrated by recent events, the question of improving the gas turbine so that it will, in its particular field, prove of equal importance and value, has attracted a good deal of attention and study. The development of the reciprocating gas engine has been of comparatively recent date, and this is receiving considerable attention in many fields. It furnishes a whole history of unique adaptation of means to an end, and almost every month some new reports of discovering better methods of utilizing the waste gas of blast furnaces in the gas engine reopen the old questions relative to this machine. There are possibilities in this direction which are only faintly conceived and appreciated today, and within the next decade revolutions of considerable magnitude in gas-engine operation will be realized.

The reciprocating gas engine is today for certain work, and under favorable conditions, the most efficient and economical engine in operation. But it has fatal limitations in making it of general use outside of its proper limits. It cannot compete with the steam engine in converting the stored-up energy of coal as a fuel into mechanical energy. The reciprocating gas engine is a large affair compared with a steam engine of equal horsepower. This question of size is one of its disadvantages. It has not been developed yet so that it is double-acting, as the steam engine. That is, it has but one explosion every two revolutions, while the double-acting steam engine admits steam twice at every revolution. The comparative efficiency of the two in this respect is, therefore, in the ratio of 4 to 1. But improvements have already decreased this seeming difference in efficiency by increasing the working range of pressure of the gas engine.

The adaptation of the turbine to the gas engine may in time completely overcome the difficulties and disadvantages which make this machine much less satisfactory than steam engines for most ordinary purposes. If gas explosions can be made to take the place of the steam jets as delivered through the nozzles to the buckets of the wheel, it may create a revolution in mechanical power and energy quite startling. It would immediately increase the capacity of the gas engine, and reduce its weight and size. The present cooling jacket of the gas engine could also be done away with, and as this is one of the clumsiest and most objectionable features of the gas engine, the gain would be enormous. The cooling, or water-jacket, of the gas engine has been found necessary to preserve the working life of the engine. The temperature of the exploding gas is so high that it would rapidly deteriorate the different parts of the gas engine if there was not a cooling jacket surrounding the most exposed parts to reduce the temperature. The loss through this in efficiency is great. The heat carried off by the cooling water varies in different machines, but it is estimated to represent all the way from one-sixth to one-fifth of the heat delivered by the exploding gas to the engine. The saving of this waste alone by dispensing with the water-cooling jacket would be an important item.

The gas-turbine engine is a machine of the future, rendered somewhat difficult of construction and design, because of the present imperfect control of gas combustion. Should science demonstrate a method of controlling this combustion so that it would be continuous under pressure instead of

in a series of explosions, the gas turbine would almost instantly become a reality, ready to compete in the same field with the steam or reciprocating engine. It is not considered a physical impossibility to control gas under pressure so that its ignition and combustion will be continuous, and experimenters have already made remarkable and encouraging tests in this direction. If such an improvement is accomplished we may within a few decades do away with the steam boiler for certain lines of work entirely. The power of the fuel will be conducted directly in the form of gas to the turbine wheel, and then delivered to run electrical generators or ordinary machinery now operated by steam.

The gas engine has come to stay in many departments of work, but at present only where the conditions are very favorable, or where it is necessary to utilize the waste gas of blast furnaces. But the gas turbine is something which engineers now are working upon with the hope of ultimate success. If ever worked out satisfactorily it will mark one of those revolutionizing epochs in the world of power and mechanics which completely change old conditions.

SAFETY DRESS FOR ELECTRICIANS

PROFESSOR ARTEMIEFF has invented a safety dress for the protection of electricians and others working around high-tension apparatus. The safety dress is constructed of fine but thickly woven wire gauze, and covers the feet, head, and hands. It is stated that the dress was tested in the high-tension laboratory of Siemens and Halske, and that throughout the tests the experimenter declared that he did not feel the slightest sensation of any current through his body.

The total weight of the dress is 3.3 pounds, its resistance from hand to hand .017 ohm, and its electrostatic capacity varies from .0002 up to .0025 microfarad, according as the wearer is far away from or near a wall. The cooling surface is such that a current of 200 amperes can pass through the dress for some seconds from hand to hand without any perceptible heating effect.

Standing uninsulated on the ground and clad in this garb, the experimenter drew sparks from the secondary terminals of a transformer which was developing 75,000 volts at a frequency of 50 cycles per second. He next seized the main and when the potential was raised to 150,000 volts he drew sparks from both terminals and handled the latter. The machine supplying this transformer was of 170 kilowatts capacity. In concluding the experiments the inventor short-circuited this generator by touching both of the terminals, the potential difference between the two being 1,000 volts, and the current 200 amperes. The circuit was broken by simply letting go of one of the terminals.

Rule for finding the required quantity of air for the complete combustion of 1 pound of coal of a given composition: Let the constituent carbon, hydrogen, and oxygen be expressed as percentages of the total weight of the coal. To the carbon add three times the hydrogen, and from the sum deduct four-tenths of the oxygen. Multiply the remainder by 1.52. The product is the quantity of air at 62 degrees F. in cubic feet required.

THE INDUCTION MOTOR—I

R. B. WILLIAMSON

THE direct-current motor has been in use so long that its operation is well understood by nearly all who are called upon to look after such motors. The same cannot, however, be said of the alternating-current induction motor. This is no doubt partly due to the fact that the general use of induction motors is of comparatively recent date, and also to the fact that many of the explanations regarding it have involved the use of a great deal of mathematics. The object of the present articles is to endeavor to give a simple explanation of the working of such motors without going into mathematical demonstrations. That is, no attempt will be made to make any calculations regarding these motors, the object being to simply point out the principles that govern their operation.

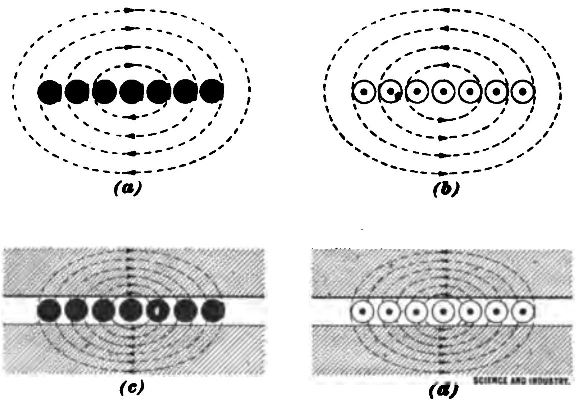


FIG. 1

If we take an ordinary direct-current motor and, after making sure that the field is excited, allow current to flow through the armature, the armature will revolve and if a load is applied at the pulley, the amount of current that the armature takes from the mains will depend on the load; the greater the load the greater the current. In this case, therefore, the armature is made to revolve by sending current into it from an outside source. Now, suppose we consider another method of making it revolve—a method that would never be used in practice, but which will aid in understanding the operation of the induction motor. Suppose that the brushes and brush holders are removed entirely and that a copper ring is pressed on over the commutator, thus connecting all the commutator bars together. What will be the result of this? In the armature winding of a direct-current motor there are numerous coils, the terminals of which are connected to the commutator bars. Now, if the bars are all connected together, it follows that the armature coils are short-circuited by the copper ring and that therefore if any E. M. F. is set up in these coils there will be a closed path for currents to flow in. That is, if we can set up E. M. F.'s in the coils we can produce currents in the armature without connecting the armature to any outside source of current. Now, imagine the armature to be held from turning and the excited field revolved around it. The magnetism sweeping around the stationary armature will induce E. M. F.'s in the various coils and, since these coils are short-circuited, heavy currents will flow. These currents will react on the field just as in a direct-current motor, and there will be a strong drag or turning effort exerted on the armature. If, therefore, the armature is released it will be dragged around, and if a load is applied to the pulley it will be driven

just as effectively as if the armature were supplied with current from an outside source. The armature will never run at as high a speed as that at which the field is driven, because if it ran just as fast it is evident that there would be no cutting of lines of force by the armature conductors, because they would be turning around just as fast as the field, and hence there would never be any relative motion between field and conductors.

In the case just mentioned, the currents were set up in the armature by means of a rotating magnetic field, and this rotating field was obtained by actually revolving the field structure around the armature. Now, it will be shown later that by using suitable windings and supplying these windings by two or more alternating currents that differ in phase, a revolving magnetic field may be set up without actually revolving the field structure with its windings. This revolving field can set up currents in a closed-circuit armature and drag it around just as effectively as the revolving-field structure just described. Although the field frame itself stands still the magnetic poles set up by the currents in the windings are constantly shifting, or sweeping around the armature, and thus induce currents in the armature conductors. It is because of the fact that the current is induced in the armature instead of being led into it from an outside source that these machines are called induction motors.

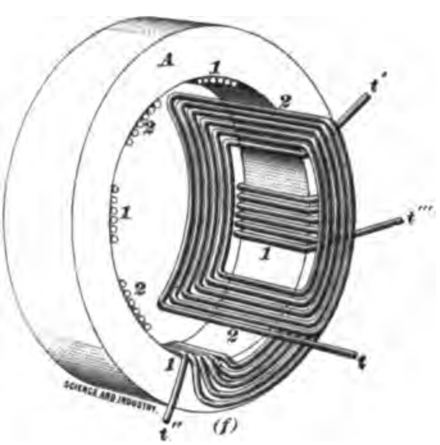


FIG. 2

Before looking into the manner in which the revolving field is set up, let us review a few elementary points regarding the relation between the direction of a current and the magnetism set up by the current. Fig. 1 (*a*) represents a cross-section of a band of seven conductors supposed to be standing at right angles to the plane of the paper. The current in each of these conductors is flowing downward through the paper, and this is represented by filling the circles in black. Magnetic whirls or lines of force will be set up around the wires and their direction can be indicated by sprinkling fine filings around the wires. The general direction of the lines is about as indicated by the dotted curves, and when the current is flowing downward these whirls are assumed to be directed clockwise, or in the same direction as the movement of the hands of a watch, as indicated by the arrowheads. If the current flows up (indicated by a dot in the center of the wire, as shown at *b*), the lines are in the opposite direction or counter clockwise. If the bands of the conductors are placed between two masses of iron as in (*c*) and (*d*), the direction of the magnetic lines remains the same as before, but the number of lines for a given current is enormously increased, because the greater part of the path provided for the lines is now through iron, and iron is a very much better conductor of magnetism than air.

Coming back to the subject of the revolving field, suppose we have a laminated iron ring *A*, Fig. 2, and

around the inside face of this ring arrange four flat coils of six turns each. In the figure only two complete coils are shown, but the four groups of conductors, *1*, *1* and *2*, *2* are connected in exactly

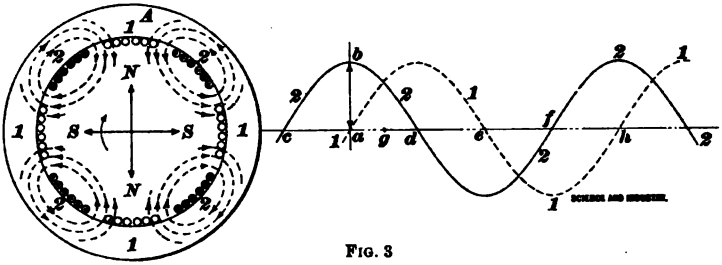


FIG. 3

the same way as the two coils indicated. The terminals of one coil are $t\,t'$ and of the other $t''\,t'''$. Coil $t\,t'$ and its mate on the opposite side of the ring are connected in series, and coil $t''\,t'''$ and its mate opposite are also connected in series, thus giving two circuits consisting of two coils each. By supplying these two sets of coils with suitable alternating currents, the magnetism set up will sweep around the inner face of the ring, although the structure *A* with the coils remains stationary, and if a closed-circuit armature were placed inside the ring it would revolve. In other words, we would have an alternating-current induction motor. For the present, however, we will leave the

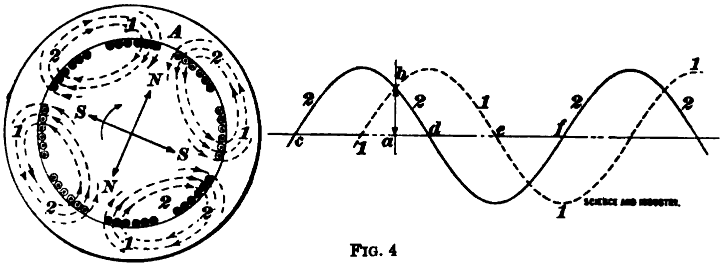


FIG. 4

armature out of account and confine our attention to the revolving field.

Fig. 3 shows the ring with its eight bands of conductors. The bands marked *1*, *1*, *1*, *1* are connected in series forming one circuit, and those marked *2*, *2*, *2*, *2* are in series and form another circuit, which is entirely distinct from the first. In order that this winding may set up a revolving field it must be supplied by two currents that differ in phase by one-quarter of a cycle. For example, group of coils *1* is connected to one source of alternating current, and group *2* to the other, and the two currents are related to each other, as shown by the wave curves in Fig. 3. The dotted curve *1–1* represents the flow of current in the conductors marked *1*, while the full line curve represents the current in conductors *2*, *2*. The interval of time represented by the distance $c\,f$ or $a\,h$ represents the time that it takes either current to pass through one complete cycle, consisting of positive and negative half waves. For example, if the frequency were 60 cycles per second, then the distance $c\,f$ would represent one-sixtieth of a second. The distance from c to a represents the time for one-quarter of a complete cycle, and current *1* is displaced from current *2* by the distance $c\,a$, i. e., by one-quarter of a cycle, so that when current *2* is at its maximum value $a\,b$, current *1* is passing through its zero value. Two currents that differ in phase in this way constitute a two-phase system, and when supplied to the windings previously described, are capable of setting up a revolving magnetic field.

In Fig. 3 suppose we consider the instant of time at the point *a*. At this instant the current in conductors *1*, *1* is zero, because curve *1* is just crossing the horizontal. The current in conductors *2*, *2* is at its maximum value represented by the vertical *a b*, and we may therefore mark the direction of the currents in the various conductors, as shown. In groups *2* the current will flow alternately up and down, while in groups *1* there will be no current. Magnetism will be set up around the groups that are carrying current, as already explained, and the direction of the magnetism will be as indicated by the arrowheads on the dotted lines. Wherever the lines emerge from the iron structure there will be a north pole, aud where they enter there will be a south pole, so that four poles *N*, *S*, *N*, *S* will be formed, the letters being placed opposite the centers of the poles. Now take an instant one-eighth of a cycle later, as shown in Fig. 4. The value of each of the currents is now indicated by the vertical *a b*, and the currents in each group of coils are equal and in the same direction. They will therefore flow, as shown by the marking of the conductors, and four poles will be formed with their centers in the directions indicated. Fig. 5 represents the state of affairs another eighth of a cycle later. The current in conductors *2* has now become zero, and the current in *1*, as indicated by the vertical line, is at its maximum. All conductors *2* are now without current, and the poles are formed as shown. Fig. 6 shows the condition another eighth of a cycle

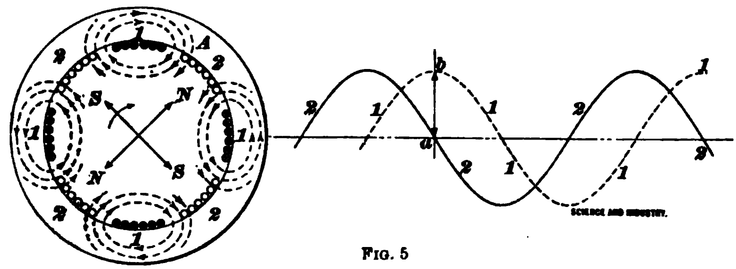


FIG. 5

later. The current in conductors *1* is now represented by the vertical *a b*, and it is in the same direction as in Fig. 5, but less in amount. The current in conductors *2* is represented by *a b′*. It is equal to the current in conductors *1*, but it is in the opposite direction. In fact, the condition is the same as shown in Fig. 4, except the current in groups *2* is reversed, and these groups in Fig. 6 are therefore marked in the opposite manner from that shown in Fig. 4. Fig. 7 shows the condition another eighth of a cycle later. Current *1* has now become zero, and current *2* is at its maximum in the negative direction. This figure is the same as Fig. 3, except that the current

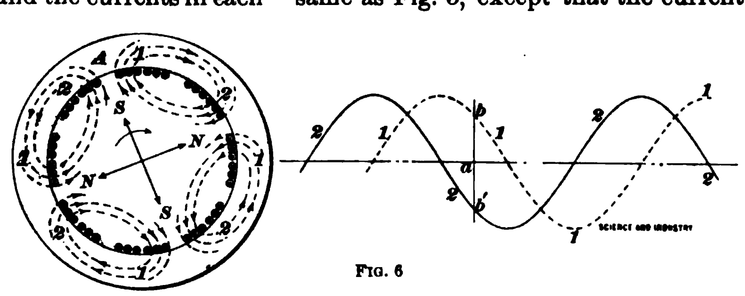


FIG. 6

in groups *2* is reversed. It will be noticed in these figures that as time elapses, the poles gradually shift around. During half a cycle the four-pole field has shifted one-quarter of a revolution,

and two complete cycles would carry it through a whole revolution, or in general,

$$\text{Number of revolutions per second} = \frac{2 \times \text{frequency in cycles per second}}{\text{number of poles}}.$$

The rate at which the magnetism revolves when set up by currents of given frequency can therefore be made any desired amount by winding the field for a suitable number of poles. A field wound for eight poles and supplied with 60-cycle current would revolve 15 times per second or 900 per minute.

To illustrate the production of a revolving field we have taken two currents displaced by one-quarter of a cycle and a winding or set of windings

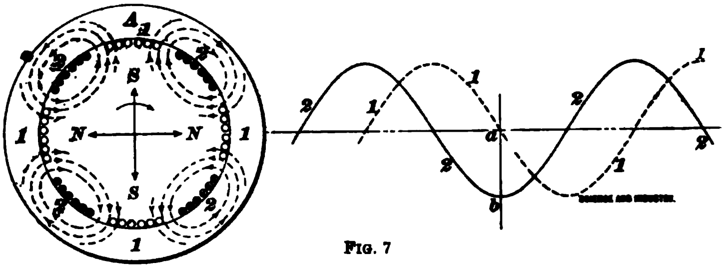


FIG. 7

correspondingly displaced regarding each other on the field structure. A revolving field can also be set up by using more than two currents with a corresponding arrangement of windings. For example, three currents differing in phase by one-third of a cycle supplied to three sets of windings make up the three-phase motor so widely used. The result is, however, the same in either case; a rotating magnetism is set up, as described, and this rotating magnetism is capable of inducing currents in a rotating armature, placed within the field, provided the armature always revolves at a little lower rate than the field.

On account of the fact that the magnetism set up in the field induces currents in the armature, the stationary part or field of an induction motor is often called the primary, and the armature the secondary, on account of the similarity in their action to the primary, and secondary, coils of an ordinary transformer. In a transformer, the secondary is fixed with regard to the primary, and the E. M. F. induced in the secondary is made use of to set up currents in an outside circuit. On the other hand, in the induction motor, the secondary is free to move with regard to the primary, and the secondary currents are not used to perform work in an outside circuit but to produce motion between the primary and secondary, and perform mechanical work at the pulley. Evidently, as the load increases, the currents in the armature must also increase, and this means that a higher E. M. F. must be set up in the conductors. In order to obtain this higher E. M. F. there must be a greater relative cutting of lines of force by the conductors, and this is brought about by a slight lowering of the armature speed. The magnetic field revolves at a constant speed so that any decrease in the speed of the armature means a greater cutting of lines of force. The speed of an induction motor therefore falls off slightly as the load increases, and in this respect it behaves like a shunt-wound direct-current motor. The difference between the speed of armature and rotating magnetic field is called the *slip* of the motor.

In the above description we have spoken of the part which sets up the revolving field as the stationary part of

the motor, though it is possible to have it form the rotating part. Very few motors are now built with the field as the rotating member, because this construction necessitates the use of collector rings, and moreover it is much better to make the coils, which have to stand the line pressure, stationary and let the lightly insulated conductors of the secondary be placed on the revolving part. Owing to the fact that it is possible to have the field and armature either the stationary or revolving members the two parts are sometimes referred to as the stator (stationary part), and rotor (rotating part), without reference as to the duties which each part performs electrically.

The foregoing is intended to show in a simple manner the production of a rotating field and its bearing on the action of the motor. In a subsequent article we will take up the construction of the motor and show how this principle is made use of in the actual machine, and point out some features regarding the construction of these motors.

OILS AND GREASES

WILLIAM K. RICHART

PETROLEUM furnishes the base of a great many kinds of lubricants, both in liquid and solid, or condensed, form. Paraffin cup grease, which is now largely used in this country, is made from 25° gravity paraffin oil, obtained from the redistillation of the residue of petroleum. The residue is collected from time to time until enough is obtained to fill the still, and the tar, as the oil refiner calls it, is run over or redistilled, and the product is paraffin oil of the several different consistencies and specific gravities. In the earlier stages of petroleum refining it was the custom to throw away all the residue or by-products except the distillates or what are known as refined oils, such as benzine, kerosene, headlight, etc., and it was a common sight to see heaps of heavy liver-colored oil lying on the ground in the vicinity of the oil-storage tanks that had been allowed to go to waste. In later years these by-products were found to be useful in the manufacture of lubricants and commercial articles.

Petrolatum or vaseline is made from the settlings from storage tanks. Crude oil standing in tanks for a few months collects a large amount of heavy, thick, waxy-structured oil, which will not run through the pipe lines. This was one of the products that was formerly wasted until it was found to be useful in making vaseline, by heating it to 240° F. and running it through a nest of filters of bone charcoal, which bleached it, giving it a lighter color; by continuing this process several times through this filter a cream-white color is produced.

The filter used by the oil refiner for filtering the different products of petroleum, consists of a funnel-shaped receptacle with a steam coil around the outside to heat the oil. The oil passes through bone charcoal, which is the filtering material used by the oil refiner. The oil drops from one filter to the other until it has passed through several filters and the desired shade is attained. This process of filtering oil is considered the correct one, and a good substantial filter can be made for any engine room by simply introducing a funnel in a cylindrical tank and having a gauze at the bottom of the funnel; by filling it about two-thirds full

of bone charcoal it will be found to be a very desirable and useful filter.

The viscosity of an oil can be increased by precipitating a pound of oxide of lead in a gallon of commercial olive oil, and after precipitation has taken place it will be found that the olive oil has become oxidized. By the addition of 20 per cent. of this prepared oil to 80 per cent. of engine or dynamo oil, it will increase the viscosity or active principle of the oil about one-third.

There is another method of treating oil by the addition of what is known as mineral gelatine to 25° paraffin oil. The proportions are about 1 to 5. This produces what is known as mineral castor, or cast machine oil. Mineral gelatine is manufactured by a process of saponification, which congeals the mineral oil into an emulsion, as petroleum cannot be made into a solid soap with alkalies. Cylinder oil is rendered much more efficient for high-pressure valve lubrication by the addition of 5 per cent. of olive oil in connection with acidless tallow oil, the formula being as follows: 80 per cent. of 600° steam-cylinder stock, 15 per cent. acidless tallow oil, 5 per cent. commercial olive oil. Combine these at a temperature of 240° F. This formula makes the highest grade of cylinder and valve oil, and for those who wish to compound their own oil it will be found very economical to use, as the cylinder stock can be purchased in the market for much less than the compounded cylinder oil.

The regular commercial cup grease of the several consistencies is made according to the following formula: 60 per cent. 25° paraffin oil, 30 per cent. animal fat, 10 per cent. air-slacked lime. The lime is first incorporated with the animal fat, which has been previously heated at a temperature of about 90° F. and placed in a tank directly over a kettle where the grease is to be made. A small tank is placed opposite containing the paraffin oil. These two, the oil and the compound, are allowed to flow into the kettle slowly together, until they get up to a point of heat at which they amalgamate or saponify. As soon as this point is reached it is necessary to remove from the kettle and cool as quickly as possible, and in order to insure perfect smoothness it may be run through a paint mill to thoroughly crush any lumps or specks that may be in it. This compound is largely used in this country, and the only drawback it seems to have is when used in compression cups. When the pressure is kept on continuously it has been found to separate the mineral oil from the animal, and leave a residue in the cup that will not pass through the feed holes. This can be obviated, however, if cups of the screw-down type are used instead of the spring compression cups.

A very good lubricant for hot journals is made from the following formula: 10 pounds of palm oil, 10 pounds of tallow, and 20 pounds of cylinder stock, 5 pounds of lime and 2 ounces of sulphur. This, compounded at about 220° F., and agitated while cooling, will produce a very good lubricant for hot journals. This compound is usually flavored with the oil of myrbane to give it that peach-stone flavor that greases usually have.

A good cold-process axle grease is made in the following manner: 50 pounds of first-run rosin oil and 15 pounds of air-slacked oil are incorporated and added to 35 pounds of cylinder stock or residuum oil; the whole is thoroughly mixed and allowed to set in boxes or pails.

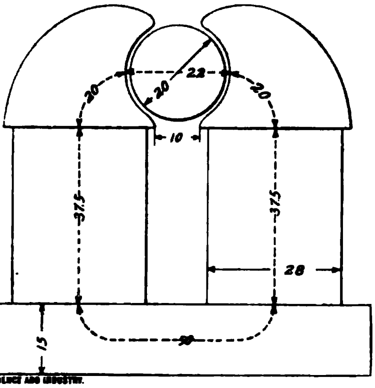
This will be found to be a very good lubricant for a spindle or axle.

ELEMENTARY PRINCIPLES OF ELECTROMAGNETS—V

A Practical Example

IN previous articles under this title the principles of the magnetic circuit and the winding of coils have been explained. It may be well to now illustrate some of these principles by working out one practical example. In the accompanying figure is shown the magnetic circuit of an ordinary bipolar dynamo-electric machine, either a dynamo or motor. The dimensions are given in the figure in centimeters. The length of the armature core or body and the width of the pole faces are each 30 centimeters and the width of the yoke 43 centimeters.

Suppose that a magnetic flux of 6,000,000 lines of force is required



through the armature and that the leakage coefficient is 1.3. This means that $6,000,000 \times 1.3 = 7,800,000$ lines of force must be developed in the core in order to get 6,000,000 through the pole pieces, air gaps, and armature. The difference, 1,800,000 lines, leaks from one core to the other without passing through the pole pieces, air gaps, or armature. The average length of the magnetic circuit through the various portions is shown by the dotted lines and the figures upon them.

We will determine the magnetomotive forces and ampere-turns for the various portions of the magnetic circuit, then the total number of ampere-turns required, the depth and length of winding, the proper size wire, and the amount of heat developed. The armature we shall assume to be made of soft sheet iron, for which magnetization and ampere-turn curves are given in Figs. 3 and 1, in SCIENCE AND INDUSTRY for June and July, 1902, respectively. The cores, yoke, and pole pieces we shall assume to be cast steel, for which similar curves are given in the same figures referred to above.

Let us first compute the ampere-turns required for the armature. The sectional area of the armature, normal to the lines of force, is equal to $20 \times 30 = 600$ square centimeters. Hence, the magnetic density $= \frac{6,000,000}{600} =$ 10,000 lines per square centimeter. From the curve for sheet metal in Fig. 3, in SCIENCE AND INDUSTRY for June, 1902, we find that the magnetizing force per square centimeter is about 3. This multiplied by the length of the magnetic circuit in the armature, which is practically 20 centimeters, gives $3 \times 20 = 60$, as the magnetomotive force required for the armature. We may say that the magnetomotive force is 60 gilberts, if we prefer to use a name for this unit.

The number of ampere-turns required to force 6,000,000 lines through the armature $= \frac{60}{1.26} = 47.6$. By means of the curve in Fig. 1, in SCIENCE AND INDUSTRY for August, 1902, the ampere-turns per centimeter length may be obtained directly from the magnetic density. From this figure we obtain about 2.5 as the ampere-turns per cen-

timeter; then, 2.5×20 (the length of the magnetic circuit in the armature) $= 50$ ampere-turns required for the armature. This is about as close as results obtained in the two different ways will agree, due partially to the unavoidable reduction in the size of the original curves in order to make suitable sized figures. Where ampere-turn curves are available the latter method, being simpler and shorter, is the preferable one.

Let us now determine the ampere-turns required for the two air gaps. Each air gap has a length of 1 centimeter, giving 2 centimeters for the total length of both air gaps. Since both air gaps are similar in length and area, only one of 2 centimeters' length need be considered. The circumference of the inside edge of the pole pieces $= \pi \times d = 3.1416 \times 22$. The distance between the pole pieces is marked 10 centimeters; hence, the area of one polar surface $= \frac{[3.1416 \times 22 - (2 \times 10)] \times 30}{2} = 736.7$ square centimeters. The density in the air gap is then $\frac{6{,}000{,}000}{736.7}$ lines per square centimeter. Now, the permeability of air is 1; hence, the magnetizing force is equal to the magnetic density. The magnetomotive force for the air gaps, since the length is 2 centimeters, $= \frac{6{,}000{,}000 \times 2}{736.7} = 16{,}287$ gilberts. The ampere-turns required $= \frac{16{,}287}{1.26} = 12{,}926$.

It is sufficiently correct to consider the area of the pole pieces the same as the air gap, namely 736.7 square centimeters. Then the magnetic density $= \frac{6{,}000{,}000}{736.7} = 8{,}143$. From the curve for cast steel in Fig. 1, in SCIENCE AND INDUSTRY for August, 1902, we find that the ampere-turns per centimeter length corresponding to a density of 8,143 is about 3. Then the ampere-turns required, for both pole pieces, each having a magnetic circuit of 20 centimeters' length $= 3 \times 20 \times 2 = 120$.

The cores, which are cylindrical, have a sectional area of $28^2 \times .7854 = 616$ square centimeters. The magnetic density would then be $\frac{6{,}000{,}000}{616}$, provided there was no magnetic leakage. But we have assumed a leakage coefficient of 1.3; hence, the density required in the cores $= \frac{6{,}000{,}000 \times 1.3}{616} = 12{,}662$ lines of force per square centimeter. From the same curve that we used for the pole pieces, we find that the ampere-turns per centimeter corresponding to this magnetic density is 12. The length of both cores $= 37.5 \times 2$; hence, the ampere-turns required for both cores $= 12 \times 37.5 \times 2 = 900$.

The yoke has a width of 43 centimeters; hence, its sectional area $= 15 \times 43 = 645$ square centimeters, and its magnetic density $= \frac{6{,}000{,}000 \times 1.3}{645} = 12{,}093$ lines of force per square centimeter. In the same manner, as for the core, we find the ampere-turns per centimeter corresponding to this density to be 9. Since the length of the magnetic circuit in the yoke is, according to the figure, 50 centimeters, then the ampere-turns required for the yoke $= 9 \times 50 = 450$.

Then the total number of ampere-turns required to produce a flux of 6,000,000 lines through the armature, assuming a leakage coefficient of 1.3, $= 50 + 12{,}926 + 120 + 900 + 450 = 14{,}446$ ampere-turns, or, $\frac{14{,}446}{2} = 7{,}223$ on each core.

Let us suppose that the voltage across both coils, which are to be

connected in series, is 50 volts. Then we can use formula 1, page 483, in SCIENCE AND INDUSTRY for August, 1902, which is $A = \frac{12 \times l \times IT}{E}$. Over the core must be placed at least .1 inch, say we allow .2 inch, of insulating material.

This will make the diameter of the inside of the coil $\frac{28}{2.54} + .4 = 11.4$ inches. Let us try making the depth of the coil .9 inch. Then the outside diameter of the coil $= 11.4 + 2 \times .9 = 13.2$ inches, and the length of a mean turn $= \frac{\pi}{12}\left(\frac{11.4 + 13.2}{2}\right) = 3.22$ feet. Then the sectional area of the wire required, $A = \frac{12 \times 3.22 \times 7{,}223}{\frac{1}{2} \times 50} = 11{,}164$ circular mils. This would be a wire between Nos. 9 and 10 B. & S.

Let us see if No. 9, the next larger size, will satisfy all conditions. There will have to be an insulating collar, say .25 inch thick, at each end of the coil. The length of the winding space then $= \frac{37.5}{2.54} - .5 = 14.3$ inches. In one layer there will be, according to Table II, in SCIENCE AND INDUSTRY for September, 1902, $7.66 \times 14.3 = 109$ turns. According to the same table there will be 8.42 layers of No. 9 wire to the inch, or $8.42 \times .9 = 7.6$ layers in the depth of the coil assumed. Then there will be $109 \times 7.6 = 768$ turns in each coil. The ampere-turns required were found to be 7,223; hence, the current will be $\frac{7{,}223}{768} = 9.40$ amperes.

The total length of No. 9 wire required for each coil $= 768 \times 3.22$ (mean length of one turn) $= 2{,}473$ feet. The resistance of 2,473 feet of No. 9 copper wire $= .000791 \times 2{,}473 =$ 1.956 ohms. The resistance of both coils will be 3.91 ohms. This would give $\frac{50}{3.91} = 12.78$ amperes when the coils were cold. According to formula 6, in SCIENCE AND INDUSTRY for September, 1902, the rise in temperature will be $t° = \frac{80\,W}{A} = \frac{80 \times 50 \times 9.4}{\pi \times 13.2 \times 14.3 \times 2} = 31.7°$ F. This is certainly a safe rise in temperature.

Now, copper increases in resistance .0022 per degree F. per ohm; hence, the increase in the resistance of the copper wire, when as hot as it will get, $= 3.9 + 3.9 \times .0022 \times 32 = 4.17$ ohms. The current will then be $\frac{50}{4.17} = 11.9$ amperes. This is more than the current required, which is 9.4 amperes. This would allow the use of a regulating resistance in series with the coils. If it is desired to have no external resistance when the coils are hot, it will be necessary to wind more or less of each coil with No. 10 wire and calculations, similar to these that we have made, may show that the whole coil could be wound with No. 10 wire. This would reduce the current and hence make the efficiency somewhat greater anyway.

Assuming that No. 9 is used, however, let us see how many watts will have to be radiated per square inch of the outside cylindrical surface of the coils. The total number of watts to be radiated from each coil $= \frac{50}{2} \times 9.4 = 235$; hence, the watts per square inch $= \frac{235}{\pi \times 13.2 \times 14.3} = \frac{235}{593} = .4$ watts per square inch. Consequently, the coil will not overheat. This was already indicated by the previous calculation, which showed that the rise in temperature would not exceed 32° F.

MECHANICAL BOILER CLEANING

THE time and patience lost in cleaning boilers by the old, slow methods seem in a fair way to become too antiquated for modern industrial purposes, and the up-to-date mill and steam plant will be equipped with mechanical boiler cleaners, which will do the work in half the present time and with much greater completeness. Inventors have sought to design types of boilers which could be automatically cleaned, or which could at least be reached by some method that would greatly minimize the amount of time and labor ordinarily expended upon such work. An engineer who is careful in his work realizes the necessity of keeping his boilers in good condition, and to clean them at regularly stated times is a part of the business essential for the proper working efficiency of the steam plant. In cleaning large boilers, where there is sufficient room inside to accommodate the cleaners, there has always been some difficulty in adequately lighting up the interior for careful inspection. It should be generally accepted, as a matter of expediency, that a thorough inspection of the interior of a large boiler should be made at the time of cleaning. The weakness of a large boiler can often be detected in this way from the inside when no outside signs of it are visible. Consequently, inspection and inside cleaning should always be made at the same time.

To accomplish this, however, the cleaners and inspectors must have a light which will reveal every part of the inside. Heretofore various sorts of lights have been used, and in some cases with dire results. An open torch or lamp is used today in many plants, but the cleaners always experience difficulty and unpleasantness from their use. There is, in addition to the inconvenience, actual danger from suffocation from the smoke and fumes and the igniting of the clothes of the men working in such narrow quarters. A number of explosions of kerosene and gasoline lamps in the hands of boiler cleaners have resulted in the serious wounding of the men, and this is now commonly dreaded by cleaners. The smoke from the lamps also tends to blacken the sides of the boiler and the clothes of the men.

In boiler cleaning today, where the interior is large enough for the men to enter, the electric lamp designed for this particular purpose has come into general use. By means of this the cleaner is protected from any danger and unnecessary inconvenience. As most engineers or firemen clean their own boilers, the invention is made in their interests rather than in that of the manufacturers. The electric lamp, of course, is available only where electricity is used in some form at the plant; but as this is the case in a great many steam plants throughout the country the application is quite common. By means of a flexible conductor, carefully insulated, the portable electric lamp can be supplied with light by simply attaching it to the lighting system of the mill. The incandescent bulb is covered with open wirework so that the glass cannot be broken by coming in contact with the iron of the boiler. Another accommodating attachment of the electric lamp is an electromagnet which enables the cleaner to stick the bulb upon any part of the ironwork. This is of great convenience, for inside the boiler there is nothing on which to hang or place a lamp, and if put down it will generally

roll sidewise and threaten trouble. The electromagnet enables the cleaner to place his light in just the position he desires for careful work. The cleaning and inspection are thus apt to be more perfect than if the light is of an uncertain nature and somewhat dim.

In the matter of boiler cleaning by mechanical methods there have likewise been many improvements in recent years, and some of the mechanical devices appear to relieve the engineer and fireman of most unpleasant work. The formation and incrustation of scale particles on the inner surfaces of all classes of boilers appear to be beyond the ingenuity of man to prevent. In spite of many types of feedwater purifiers to eliminate the tendency toward interior incrustation, the disagreeable formation of scale continues. There has, of course, been a decided improvement by means of these feedwater purifiers, and the evil is greatly reduced thereby, but there is still sufficient scale formation to make frequent cleaning necessary.

Another method to prevent the formation of scale particles in the boilers has been to mix various chemical compounds with the feedwater which would counteract the tendency. One reason why it has been considered desirable to prevent the scale formation is that the constant washing and cleaning to remove it must have a certain deteriorating effect. There is no question but this work of cleaning, scraping, and washing must, in a measure, weaken and strain the boiler, and thereby actually shorten its life of usefulness. Most of the chemicals employed to prevent the formation of the scales, however, have a tendency to cause deterioration in the iron by chemical action, and it is a question in the minds of some users of steam boilers whether the old-fashioned way of cleaning and washing is not the best. The purification of the feedwater is undoubtedly the best method. The less sediment carried into the boiler with the water the less will be the tendency toward incrustation. In some localities, the foreign elements in the feedwater are so abundant that some purifier is almost essential. Without them the sediment carried in clogs up the boiler in a very short time. There have also been found in the water of some sections chemical particles held in solution and precipitated when heat is applied, which the most approved feedwater purifiers are unable to affect. The tendency of such chemicals in the water is to increase the scale formation with alarming rapidity. So heavily laden with mineral particles and chemical constituents is some water, that mills have had to draw their feedwater from a great distance in order to secure cleaner and purer water. Undoubtedly, a good deal of the trouble experienced in some regions through boiler deterioration, is directly due to the character of the water used for the boiler. A chemical examination of the water might in the end prove profitable, for it would reveal substances in it that should never be allowed to enter any iron boiler. The driving of a deep artesian well to obtain pure feedwater has thus saved many a mill owner considerable sums of money in the end.

Precautionary steps to prevent incrustation of the boilers inside are all right so far as they go, but they do not at present fully cover the whole subject. They do not prevent the boilers from becoming clogged with sediment, nor do they stop any tendency to scale formation. Therefore, until we are better equipped with methods and machinery for purifying the water absolutely, so that neither foreign sediment nor dangerous chemical compounds are introduced in the boiler, we must depend

upon methods for cleaning which will cause the least amount of strain on the ironwork, and at the same time lighten the labor as much as possible. The loss of steam efficiency through the boilers becoming coated inside with a scale of sediment is an important question to consider. It requires a far larger consumption of fuel to produce the same amount of power, because of the non-conducting properties of the lining when the boiler is thus clogged with sediment scale than if it were clean. Moreover, after the first layer of sediment and scale has formed, the process of depositing another layer on top is greatly facilitated and increased. The work then goes on so rapidly that the boiler is soon in no condition for economical or efficient work.

Mechanical boiler cleaning in some measure accomplishes results which cannot be accomplished so well either by hand cleaning from inside or by the introduction of chemicals in the washing water. All users of steam find that the simple application of well-known laws will sometimes accomplish results which the most intricate inventions of man fail to do. Thus, the mechanical boiler cleaners are based upon a few well-known facts, or laws, for their efficiency. There are, of course, mechanical features in addition which help to make the work complete. It is well known that the impurities in water separate under ordinary working pressure, and they are then held in suspension. The question of gathering the sediment and carrying it out of the rear end of the boiler is something that is first necessary. By means of the improved mechanical boiler cleaners a forced circulation of water through the boiler carries the suspended sediment to the surface of the water, and then to the rear of the boiler. There is a peculiar skimmer arrangement which keeps constantly working on the water-line, no matter how much the water may rise or fall in the boiler. When the sediment is forced by the upward current to the surface, and carried by it along toward the rear, trough-shaped wings receive it where it is immediately taken up by the floating skimmer. It is next carried by this trough to the outlet pipe by centrifugal force and into the precipitator. In this latter, the temperature is much lower, and it is arranged in such a way that the precipitation of the sediment is carried on rapidly. The foreign substance thus collected settles in the lower part of the precipitator until it is ready to be drawn off by the blow-off pipe.

The water thus cleansed is not wasted, but is returned to the boiler from the top of the precipitator, where it is perfectly freed from all particles of sediment by means of a pipe arranged for this purpose. The return circulation completes the action of the cleaner. The foreign matter has been removed, and clean water at a moderately high temperature is returned to the boiler. The effect of this is that the boiler can be cleaned of sediment in a short time in the most effective manner without shutting off the fires or materially reducing the steam. The cleansing can be carried on continuously for some time until the water from the boiler runs as clean as that going into the feed-pipe. In other words, a mechanical cleaning of the boiler can be made frequently without straining the boiler, or without stopping work to any great extent. Boiler cleaning can be made a matter of short duration, and a weekly or semiweekly occurrence.

The gain is very great in a variety of ways. There is an actual saving in money, labor, and annoyance. There is no shut down for general boiler cleaning when the feedwater is not

very clean, and this will often be the case in all localities immediately after a rain storm. In some instances a prolonged rain of weeks keeps water so muddy that unless it can be purified before entering the boiler it will carry a great amount of sediment into the pipes, so that boiler cleaning becomes a serious matter. The efficiency of the boiler in muddy, rainy weather is thus greatly handicapped in hundreds of mills and steam plants.

The gain made through reducing deterioration of the boiler is something that cannot be well measured in exact figures. No man can tell exactly all the causes which shorten the working life of his boiler, nor can he estimate the advantages accruing from preventive measures adopted; but in the end it is possible to make some sort of a conclusion which is helpful. Those who have adopted modern methods of mechanical boiler cleaning claim that the life of the ordinary boiler is prolonged from one to five years by such methods of constantly removing foreign sediment before it has an opportunity to attach itself in layers to the boiler, and thus lay the foundation for scale formations. The old method of washing and cleaning the boilers failed to prevent the sediment from becoming hard and encrusted. If left to accumulate for any length of time, it is sure to cause permanent harm, and produce immediate evils through its non-conducting properties.

A steam plant equipped with mechanical boiler cleaners of this, or a somewhat similar type, adopts the surest preventive and curative measures yet devised for avoiding boiler deterioration and poor steam efficiency. Some plants are equipped with as many as fifty of these boiler cleaners, and the inside of the different boilers is kept so clean that the amount of fuel required to produce a given pressure of steam is always kept down to a minimum. Altogether, the subject is one that users of steam are greatly interested in, and engineers must realize the necessity of their understanding the principles of the boiler cleaners to keep abreast of the times.

COMMERCIAL ALUMINUM ZINC ALLOYS

NO alloys containing more zinc than aluminum have any special valuable mechanical properties, even the alloy of equal parts of both. The alloy *Al—2, Zn—1*, reaches a tensile strength of 40,000 pounds per square inch, melts at 425° C., does not easily oxidize, and takes a fine finish. It closely resembles a high-carbon steel in character, and is the hardest and strongest of the *Al-Zn* series. Its specific gravity is 3.8. A contraction of 17 per cent. takes place during alloying. The alloy *Al—3, Zn—1*, is the most generally useful of the series. It is softer than the last, tensile strength, 35,000. It is not malleable, but yet not brittle, bending before breaking. Hence, castings may be straightened out. Specific gravity 3.4, contraction 14 per cent.; good castings are yielded. When made from pure metals it is equal to finest brass in the lathe and under the drill and fire.

Its color is equal to that of aluminum. It is used for scale beams, astronomical instruments, light machine parts, testing machines, surgical appliances, etc. Below 25 per cent. zinc the strengths of the alloys decrease rapidly. The 15 per cent. alloy can be rolled and drawn; its tensile strength is 22,330 pounds per square inch.—The Electrochemist and Metallurgist.

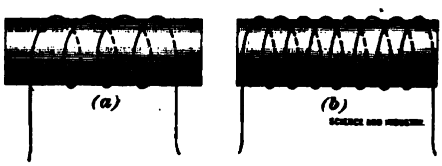
CHANGES IN MOTOR WINDINGS FOR DIFFERENT VOLTAGES

FRANCIS H. DOANE

THEORETICAL CONDITIONS—RULES FOR MAKING CHANGES

IT quite frequently occurs in connection with electric-motor work, that it becomes necessary to change the windings of a number of motors in order to use them on an electric circuit, the E. M. F. of which is very much different from the E. M. F. which the motors were designed to have impressed across their terminals. It may save the expense of selling the old motors at a sacrifice and installing a set of new motors, designed for use on the new power circuit. The cost of completely rewinding the motors is considerable and should be carefully compared to the cost of an exchange of motors. It is the object of this article to point out how the sizes of wire to be used in the rewind of the motors can be calculated approximately from the sizes of wires on the motors before the change was made. This method, while not absolutely accurate, has been found to give good results in practical work.

A few theoretical considerations would perhaps be of interest at this point. The magnetizing force of a circuit flowing through the turns of wire of a coil is proportional to the ampere-turns of the coil. The ampere-turns equal the number of turns of wire on the coil multiplied by the number of amperes of current flowing through the coil. We may have two coils of equal magnetizing forces, one having a small number of turns and a large current, and the other having a large number of turns and a small current. If the product of the amperes flowing in one coil and the turns of wire of that coil equal the product of the amperes flowing in the other coil and the turns of wire on that coil, the two coils have the same magnetizing force, provided other conditions are similar. A coil of wire consisting of 4 turns wound on an iron core is illustrated at (*a*) in the accompanying figure. On a similar core a coil of wire of 8 turns is wound as shown in (*b*). We will suppose that a current of 2 amperes flows through the (*a*) coil and a current of 1 ampere flows through the (*b*) coil. In the first case we have the ampere-turns of the first coil equal to 2 amperes, multiplied by 4 turns, or 8 ampere-turns. In the second case we have 1 ampere multiplied by 8 turns, which equals 8 ampere-turns. The magnetizing force is then the same in both cases, as the ampere-turns of the two coils are equal, and the other conditions affecting the number of magnetic lines



set up are assumed to be similar. It will also be noted that the wires on the (*b*) coil only carries one-half the current that the wire on the (*a*) coil carries. One wire will be only one-half the size of the other, and each coil can be wound in the same space, approximately. The length of wire on coil (*b*) is about twice the length on coil (*a*).

In an electric motor, current flows through the field coils and sets up magnetic lines through the frame of the motor and the armature. Current also flows through the conductors on the armature, which sets up magnetic lines around these conductors. The current flows through the armature

windings in such a manner, and sets up a magnetic flux in such a direction, that there is a constant tendency for the armature to revolve. This tendency to revolve is due to the interaction between the lines of force set up in the field and the line of force set up around the armature conductors by the current flowing through them.

The force which is exerted to move a conductor placed in a magnetic field and through which a current is flowing, equals $f = CHl$. C is the current, H the intensity of the field, and l the length of active wire. The force is proportional to the current, to the intensity of the field, and to the length of wire in the field. The force tends to drag the wire laterally, acting at right angles to the wire and to the lines of force of the field.

In redesigning the winding of a motor, or dynamo, for a different E. M. F., we must endeavor to keep the ampere-turns of the field coil the same as before and the ampere-turns of the armature the same as before. The C^2R losses in both armature and field coils should be kept about the same as the C^2R losses in the armature and field coils before the change. The C^2R loss in a coil is found by squaring the value of the current flowing in a coil and then multiplying by the resistance of the coil.

We will first consider the case of a 1-horsepower, 110-volt shunt-wound motor, which we wish to so rewind that it can be connected to a 220-volt circuit. In taking off the old windings we must make careful note of the size of wire, the number of turns of wire on the field coil, and armature coil. The number of coils and the manner of connecting the armature coils to the commutator, as well as the direction of winding and connections of the field coils.

Let us consider the field coil first. Make sure that the insulation between the field coil windings and the core is safe for the increased E. M. F. on which the motor is to be run. We find that the size of wire on the 110-volt field was a certain size of wire. The E. M. F. is to be 220 volts on the new coil, and we wish to have only one-half the current flow through the 220-volt coil, as flowed through the 110-volt coil. The watts lost in 110-volt coil if the current were C amperes is $110 \times C$ watts. Now if we have a current of $\frac{C}{2}$ and have an E. M. F. of 220 volts, the watts lost in the coil will be $220 \times \frac{C}{2} = \frac{220}{2} \times C = 110\,C$ watts. The current flowing through the shunt coil depends on the resistance of the coils and the E. M. F. impressed across their terminals. In the 110-volt coil the resistance R was of such a value that $\frac{110}{R} = C$, the current in the shunt coil. We have doubled our impressed E. M. F., and desire a current of only $\frac{C}{2}$ amperes, so we must have a total resistance of $4\,R$ or 4 times our original resistance of the shunt field circuit. We now have $\frac{220}{4\,R} = \frac{110}{2\,R} = \frac{110}{R} \times \frac{1}{2}$, (we can substitute for $\frac{110}{R}$ its value C), $C \times \frac{1}{2} = \frac{C}{2}$. Twice the number of turns of wire are wound on the 220 field coils that were on the 110-volt field coils. As the wire is one-half the size of the former wire, it has twice as much resistance per turn, and as there are twice as many turns, the resistance of the 220-volt coils will be four times that of the 110-volt coils.

The value of the current in the 110-

volt coils was C, and the number of turns B. The ampere-turns would be CB. In the 220-volt coils the current is $\frac{C}{2}$ and the coil has $2\,B$ turns, so, $\frac{C}{2} \times 2\,B = CB$. The ampere-turns of each of the sets of coils being the same. The value of the C^2R losses would be equal, as $C^2R = \left(\frac{C}{4}\right)^2 \times 4\,R = \frac{C^2}{4} \times 4\,R = C^2\,R$. The coils would occupy nearly the same space. The 220-volt coil would probably take a little more room because of the cotton insulation on the wires of the 220-volts coil occupying more space than the insulation of the 110-volt coil. The 220-volt coils should be wound with one-half the size of wire as was used on the 110-volt coils, twice the number of turns, and have a total resistance of four times as much. Put on the coils and connect them as before to the motor terminals.

The armature wires must now be calculated. We will suppose that the 110-volt armature is provided with enough coils and commutator bars so that the same number of coils, slots, and commutator bars can be used for the 220-volt armature. The E. M. F. between adjacent commutator bars should not average more than about 15 volts. The current taken by the 220-volt motor at full load will be only one-half the full load current of the 110-volt motor. The size of wire for the armature winding can then be about one-half the former size. In order to get the same number of ampere-turns per coil and per armature, twice the number of turns per coil must be used. Twice the turns multiplied by one-half the current will give the same value for the ampere-turns as before. It may be that because of the increased space taken up by the cotton insulation in the 220-volt armature coil, there will not be quite room enough in thes lot to wind in twice the number of turns of small wire. In that case wind in as near twice the turns as practicable. If there are a few less turns, the armature of the 220-volt motor will run slightly faster than the 110-volt motor armature. Connect up the new armature coils to the commutator as before.

In case it is necessary to have a new commutator with twice the number of bars in it, so as to have sparkless running, the same slots can be used, but twice the number of coils can be placed in them, each coil having the same number of turns of wire that the original coil had, but this wire being one-half the size of the 110-volt wire. There is twice the number of coils, and therefore twice the number of turns of wire on the armature, so that with one-half the former current we have the original value of the ampere-turns. A slot can have the sides of two coils go in it; if in the 110-volt winding only one side of one coil went into one slot. In case there were originally one side each of two coils in each slot, put in, in rewinding, one side each of four coils. Connect to the new commutator in the same general manner as before, taking the coils in the order that they are in the slot.

If it is desired to change winding from a high voltage to a low voltage, the same general method is applicable, only the size of wire must be increased and the number of turns of wire decreased. The current through the windings will be increased as we lower the E. M. F. and keep the capacity of the motor or dynamo the same. The ratio of transformation is obtained by dividing one E. M. F. by the other E. M. F. In case we wish to alter the windings for an E. M. F. four times

the original, we would use approximately one-fourth the size of wire and have four times the number of turns, the resistance of a coil being $4 \times 4 = 16$ times its former resistance.

When the motor is a series motor, the same method of calculation can be applied to the series coil as was applied to the shunt coil. If the E. M. F. is to be doubled, wind on the series coils twice the number of turns of one-half the size of wire as was used formerly, in order to obtain the same ampere-turns.

It is not usually desirable to change from one E. M. F. to another E. M. F. several times higher or lower, as both the commutator and number of armature slots would probably have to be altered in the case of a rise of E. M. F., and in the case of a fall in E. M. F. there would be more bars and slots than necessary for sparkless running. This method of making rewinds does not alter the efficiency or general characteristics of the motor or dynamo to any great extent. The speed may be varied somewhat by not being able to get just the proper number of conductors in the old slots, but this should not be a serious defect.

POWER

WM. O. WEBER

IT seems to the writer that not enough attention is paid to the subject of the particular kind of power best adapted to any particular factory or class of manufacture. Not enough study is given to the requirements which different classes of factories make in the way of power demand.

A cotton mill is supposed to run practically all of its machinery continuously for 10 hours per day, or as is usually the case, $10\frac{1}{4}$ hours every day but Saturday, and $5\frac{1}{4}$ hours on that day, making a total of 54 hours for the week's work. It is probably not generally well known that only about 90% of all of the machinery in a cotton mill is in operation continuously, so that the output of the factory is usually not much above 90% of the theoretical output. Still, the large percentage of steady running in a factory of this type leaves less opportunity to make economic gains by the introduction of electric drives, and the splitting up and individualizing of motors, so that given an ample water-power and an available mill sight directly adjacent to the waterfall, the shafting and belt-driven textile factory operated by water-power, still represents one of the most economical applications of nature's power forces to the industrial arts.

A shoe factory, however, makes a distinct departure from the above type of power application, where not over 75% of the machinery is producing during average working hours, and if different classes of shoes are made in the same factory, there will be seasons of the year in which whole sets of machinery will remain idle for weeks at a time. In this case, therefore, it becomes pertinent to apply individual motors of some type to short lengths of shafting, driving sets of machinery.

A still further change is noted in metal-working establishments. A manufacturing machine shop, for instance, where the machinery is only producing $\frac{6}{10}$ of the time, and where it is often advisable to operate each tool with an individual motor.

And still further along, a wood-working establishment, where the tools are only producing $\frac{3}{10}$ of the time, and

there is almost no question as to the advisability of individual motor drives.

The writer has used the term motor, not always having in mind, however, an electric motor, as he believes that a great deal of the economy which has been arrived at by the use of individual electric motors, can be very closely approximated by the use of individual steam or compressed-air motors. There are quite a number of small steam motors which are quite efficient, and it is very noticeable in factories abroad how the use of small steam engines driving different parts of factories, instead of their being coupled to one main engine, has been adopted. In Paris, the use of individual air motors is a very common practice, and in Germany the use of individual gas engines is nearly as well developed.

Recent developments in the direct compression of air by falling water, from which a very much larger net effect can be obtained by means of preheating and premoistening before using in motors, and the possibilities of distributing perfectly dry, cold compressed air long distances without serious losses, will in the near future bring the use of individual air-driven motors into greater prominence. Few people seem to realize the variation in cost of the different kinds of power, and think that all steam power costs about $23 per horsepower per annum, whereas the average cost of steam power in small factories is probably $65 per horsepower per annum. Water-power only costs from $5 to $10 per horsepower per annum. To bring some of these figures down to smaller units, the usual cost of steam horsepower for 308 days per annum, 10¼ hours per day, coal costing $3.50 per long ton, is 1¾c. per horsepower per hour, and on the basis of 365 days, 24 hours long, is only $\frac{9}{10}$ of 1c.

A gas engine using 20 cubic feet of 760 B. T. U. gas per brake horsepower per hour, gas costing 75c. per 1,000 cubic feet, would make the cost per horsepower per hour 1½c.

Gasoline engines using ⅛ of a gallon of 74° gasoline per brake horsepower, gasoline costing 12c. per gallon, would equal 1½c. as the cost of horsepower per hour.

A cost of 1½c. per horsepower per hour for electric power is extremely low, and could only be obtained from large installations. Small plants operated by steam should not expect to produce electric power for much less than 2¾c.

There being such differences, therefore, in the cost and application of power, it readily becomes an obvious question as to the type and application of power to be made for any given factory. This depends so much upon the location, nature of the business, and nearly a dozen other features, that no universal rule can be laid down. An individual study should be made of each plant. Such a study and a report on the peculiarities of the particular plant would invariably pay for itself a handsome return, especially if the recommendations were carried out in full.

Our greatest trouble in this country seems to be that we are inclined too much to copy that which has been done by our neighbors, and not to study the individual necessities of the particular plant under consideration. There is not the slightest doubt in the writer's mind that what is best for one plant is sure to be about the worst for the next adjoining one, and he is equally sure that there is a fad and fashion as to the forms of power to be used, similar to that in the wearing apparel of the fair sex.

In a subsequent article the writer will attempt to show some of the methods of measuring power by different forms of apparatus.

AN IMPORTANT POINT IN ENGINE DESIGN

W. H. BOOTH

IT has long been known that the great loss of steam in a steam engine is caused by the condensation of a large portion of it as it enters the cylinder. The reason for this condensation is as follows: Steam enters the cylinder at the boiler pressure and leaves it at the pressure of the condenser, or if there is no condenser, at the pressure of the atmosphere. The temperature of steam, unless specially dried and superheated, varies with its pressure, high-pressure steam being hotter than low-pressure steam. At a pressure of 150 pounds steam has a temperature of about 358° F. At condenser pressure its temperature is more nearly 100 degrees. The difference is 258 degrees. Think what this means. It is the difference that exists between frozen mercury and boiling water. When steam leaves the cylinder for the condenser it at once drops in pressure and its temperature falls to 100° F. Let us suppose there is water present in the cylinder. As soon as the pressure falls this water, relieved from restraint, begins to boil away into steam at 100° F. temperature. To do this it must absorb heat to the extent of 966 B. T. U. for each pound evaporated. It can only get this heat from one source, viz., the cylinder. Thus the hot cylinder boils away all the moisture on its walls, and it also radiates heat to the exhausting steam. In fact, the cylinder does its best to cool down to the temperature of 100° F. Before it can become so cold the exhaust valve closes and fresh steam is admitted to the cylinder. At once the metal of the cylinder begins to strive after the attainment of a temperature as high as that of the fresh steam. It has but one source of heat, namely, the steam itself, and a quantity of this promptly condenses and gives up heat at the rate of so many units per pound of steam condensed. It is not 966 units, but a figure something less, which can be found in the steam table of any pocketbook. The latent heat of steam is somewhat less at high pressure than at low pressure. By the time the cylinder has become as hot as the steam that is in it, quite a large proportion of the steam has been converted into water, possibly from a fifth to one-half, according to the class of engine and other circumstances. As the piston moves forward it uncovers more of the cold cylinder and more steam condenses, and the early part of the curve of expansion is more steeply inclined, as may be observed on the diagram of a sharp cut-off Corliss engine. That is, it is more steeply inclined than the proper expansion curve. As the steam expands and loses pressure, its temperature also falls, and soon the piston is uncovering fresh surface that is not so very much colder than the steam. But the piston face, and cylinder head, and the valve ports, and the early part of the cylinder barrel are now hotter than the steam, so that while steam is still being condensed on the cylinder parts just uncovered by the piston, it is being formed by the other parts of the cylinder and by the piston face. A balance has been struck between condensation and reevaporation, and the expansion curve coincides with the true curve of expansion of steam or the curve of no loss or gain of heat known as the *adiabatic* curve. The curve approximates to the ordinary hyperbolic curve. By the time the piston reaches the end of the

stroke the cylinder has become fairly cold on its inside surface, and during the exhaust, as already explained, it becomes still colder. There is thus a constant interchange of heat between the cylinder walls and the steam, to the disadvantage of economy. In the horizontal Corliss engine, the steam, which enters at the steam inlet valve, will shoot its contained water right across the cylinder into the exhaust port, and when the exhaust port is opened all water there lodging is

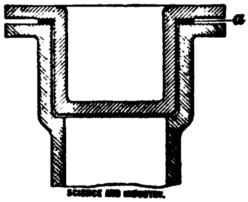


FIG. 1

promptly ejected before it has time to evaporate at the expense of the cylinder. When Corliss valves are placed in the cylinder heads this advantage is sacrificed to the advantage of reduced clearance spaces, secured by the so-called improved position. The improvement may be doubted.

The presence of water in the cylinder is thus seen to be exceedingly mischievous. Its effects are cumulative. A little water puts the cylinder into a condition to condense still more. More condenses and causes still another addition, until finally the quantity of water is so great that any further quantity is too promptly ejected to allow the mischief to grow more onerous. But the condensed water may amount to half the initial steam. Suppose, now, instead of sending ordinary more or less moist steam into the cylinder, we superheat it, that is to say, we heat the steam after it leaves the boiler to a temperature above that proper to its pressure. It is now in the condition of a perfect gas, and all the superheat must be taken out of it before any of it can be condensed. If, now, this hot and dry steam enters the cooled cylinder it is possible that the amount of superheat may be so great that the cylinder will be heated to the temperature of the steam before this has become cooled below the temperature of saturation, or that temperature below which any further cooling will cause condensation to occur. If such be the case we have now got dry steam in a dry cylinder. If there is no water in the cylinder at the beginning of the exhaust it is obvious that the cylinder cannot be cooled by the evaporation of water, and as dry steam is a poor absorbent of heat, it does not carry away much heat from the cylinder. The inner skin of the cylinder, in fact, is cooled very much less than before. When another charge of steam enters and finds the cylinder still fairly hot, this second charge is but slightly cooled, and may start expanding while still superheated. A third charge finds matters still better. As with water, so with superheat, there is a cumulative effect, and a small amount of superheat will do a great amount of good. But it is only by high superheat to 600° or 700° that all cylinder condensation can be prevented. With steam at these high temperatures it is now the practice to deprive the initial steam of part of its superheat by passing it through a series of tubes about which the exhaust steam is passing on its way to the low pressure cylinder. The excessive temperature is thus taken out of the steam and transferred to steam that has already done duty in the first cylinder or cylinders.

If the sequence of events be carefully thought over, the effect of cylinder condensation will become familiar and clear, and one point will begin to ap-

pear prominent, namely, the interior surface of the cylinder and the nature of that surface. The designer will ask himself, have I done all that is possible to reduce interior steam-touched surfaces? A once common style of cylinder was one with deep covers as in Fig. 1, the joint being made at *a*. This style of cover was often a convenience and suited certain valves. I have seen the deep projection as long as the diameter of the cylinder. There runs a narrow space between cover body, and cylinder into which steam could easily penetrate to condense and evaporate freely, and to take its full part in the mischievous cylinder action. Obviously, if designed more in accordance with Fig. 2, this mischievous space would be quite eliminated. Cases have been known where a little attention to details of this and other descriptions would reduce the interior-exposed surfaces of the cylinder to one-half or one-third of what it had been, and consequently, would very materially diminish the proportion of initial steam condensed.

Apart from mere area of enclosed surface the quality is of importance. A rough surface is really a very much greater surface when we are dealing with mere surface films of metal, say 0.01 inch or 0.005 inch in thickness. If dealing with a quarter of an inch of thickness the surface quality would be of less importance, but it is to be specially remembered that metals will carry heat through their substance more easily than they will absorb it at their surfaces, and if heat can enter a body of metal it will travel in it. Hence the use of projecting ribs in tubes of boilers. These ribs do not burn away because they carry heat to the body of the tube and to the water on the other side of this, faster than their extended surfaces can pick it up. Therefore, if the inside of a cylinder head or the piston head were cut like a file this would probably increase the trouble of condensation. A piston and and a cylinder head should be as small in area as possible, and as smooth and bright and close grained as possible, so as to diminish the rough-surface effect to a minimum. By reducing the area of a piston face I mean, of course, that the high-pitched cone-shaped pistons are to be avoided where possible.

An immense additional area is given

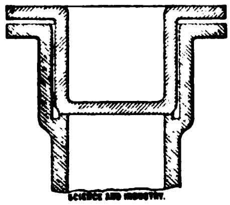


FIG. 2

by large nuts and the recesses for these. The deeply coned piston is, perhaps, stiff, but if the shape is introduced for sake of stiffness why should the maximum coning be done on the smallest pistons which require it least, being in the nature of things stiffer than large pistons. Even with superheated steam the same care should be taken to reduce surfaces to a minimum in order to secure the maximum of benefit with a minimum of superheat. Superheat is very easily lost. About 10° F. appears to disappear for each meter of length of steam pipe. In actual heat units a superheat of 100° F. represents very little in an ordinary engine per stroke, for the specific heat of steam is probably only 0.480 and the weight of steam per stroke is only small.

ROTARY CONVERTERS

SINCE the introduction of alternating currents for the transmission of power, the rotary converter has become a familiar piece of central-station apparatus. It is an interesting machine in many ways, and has a number of peculiarities not possessed by a direct-current dynamo or by an alternator. Fig. 1 shows a typical rotary converter. It is practically a direct-current dynamo of the multipolar type provided with the usual commutator and brushes, but with the addition of collector rings *a a* on the right-hand end, as shown. Three or four rings are provided, depending upon whether the machine is to be operated on a three-phase system or on a two-phase or quarter-phase system. These rings are connected to equidistant points of the winding, the exact points at which the connections are made depending upon the style of armature winding and the number of poles. Fig. 2 illustrates the principle involved. Here we have a simple ring armature in a two-pole field connected to a commutator in the usual manner. In addition to the commutator we also have the two rings *b b′* tapped to two diametrically opposite points of the winding by the wires *1 1′*. Now, suppose this armature to be driven by means of a pulley. An alternating E. M. F. will be generated in the winding, and we will obtain an alternating current from brushes *b b′* if we establish an outside circuit for the current to flow through. From brushes *a a′* we will obtain a direct current, because the commutator always keeps the brushes so connected to the winding that the current flows through them in the same direction, notwithstanding the fact that the current in the windings is alternating. The machine could then, if driven by an outside source of power, deliver direct current from one set of brushes, and alternating current from the other. It would in fact be a double-current generator, a type of machine that has come into considerable use within the last two or three years.

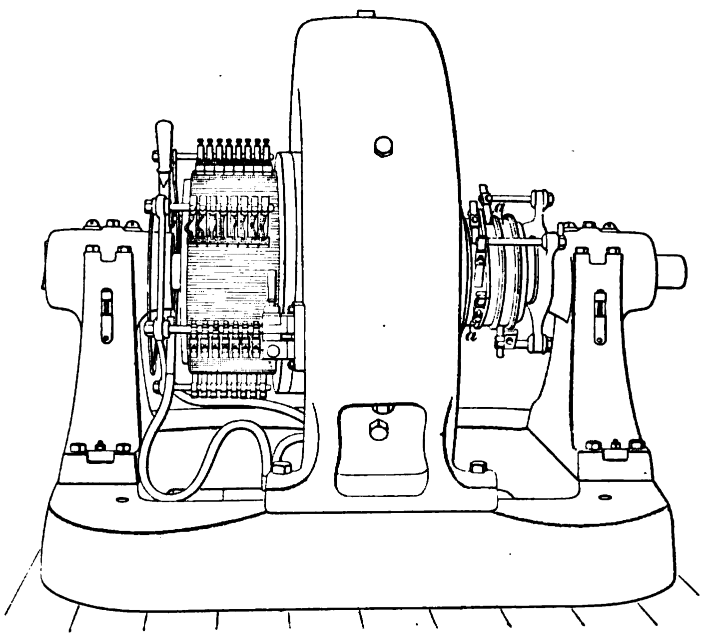


FIG. 1

Instead of driving the machine by means of a pulley, it can be driven just

as effectively by supplying it with alternating current through the collector rings. This current will drive the machine as an alternating-current motor. Now, the conductors on the armature are sweeping through the magnetic field just as much when the machine is driven as an alternating-current motor as when it is driven by a belt, so that a direct current is obtained from the brushes as before. The machine, therefore, runs as a rotary converter and converts the alternating current into direct current. In the same way it could be supplied with direct current, running as a direct-current motor, and changing the direct-current into alternating. When used in this way the machine is usually called an *inverted rotary* to distinguish it from a rotary used in the other and more usual manner. There is no difference in the two machines, the only difference lies in the method of using them.

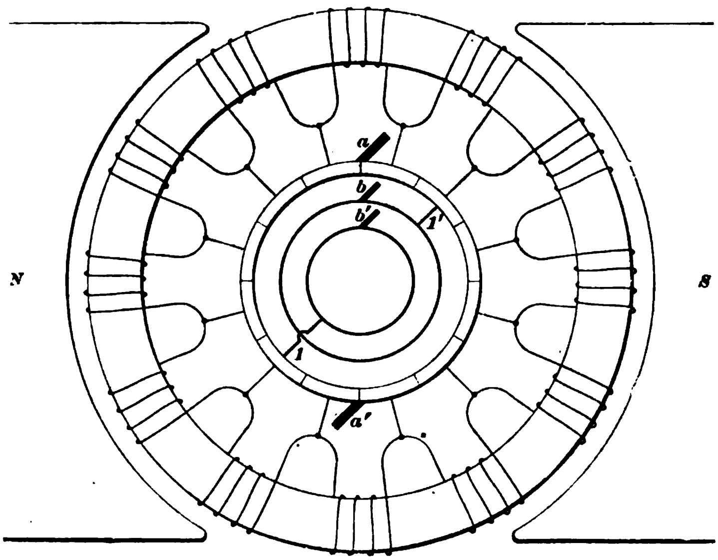


FIG. 2

The winding shown in Fig. 2 is tapped at but two points and, therefore, is suitable for single-phase current only. Single-phase rotaries are seldom used for a number of reasons that it will not be necessary to detail here. For a three-phase rotary, the winding would be tapped at three equidistant points, and the terminals brought down to three collector rings. For a two-phase or quarter-phase converter, the winding would be tapped at four points, and the terminals attached to four rings. Fig. 3 shows a winding diagram for a six-pole three-phase converter. In this case there are three taps to each ring, i. e., one tap for each pair of poles.

Rotary converters are used in most cases where alternating current has to be changed to direct current. The same result could be accomplished by coupling an alternating-current motor to a direct-current dynamo, and this combination is sometimes used for certain kinds of work, but such a transforming outfit is more expensive than a rotary converter and not as efficient. Rotary converters are probably used more largely in connection with the operation of street railways than in any other one line. Alternating-current motors are at present used but little on street railways, and it is necessary, therefore, where the power is transmitted by alternating current, to change it to direct before supplying it to the cars.

A rotary converter supplied with alternating current runs as a synchronous motor. That is, it runs at

such a speed that the frequency of its alternations is the same as that of the alternator supplying it with current. If the number of poles on the rotary is the same as on the alternator, then both machines will run at the same speed. The speed of a rotary in revolutions per minute is

$$\text{R. P. M.} = \frac{2 \times \text{frequency (cycles per second)} \times 60}{\text{number of poles}}.$$

For example, an eight-pole rotary supplied with current at 40 cycles would run at a speed of $\frac{2 \times 40 \times 60}{8} = 600$.

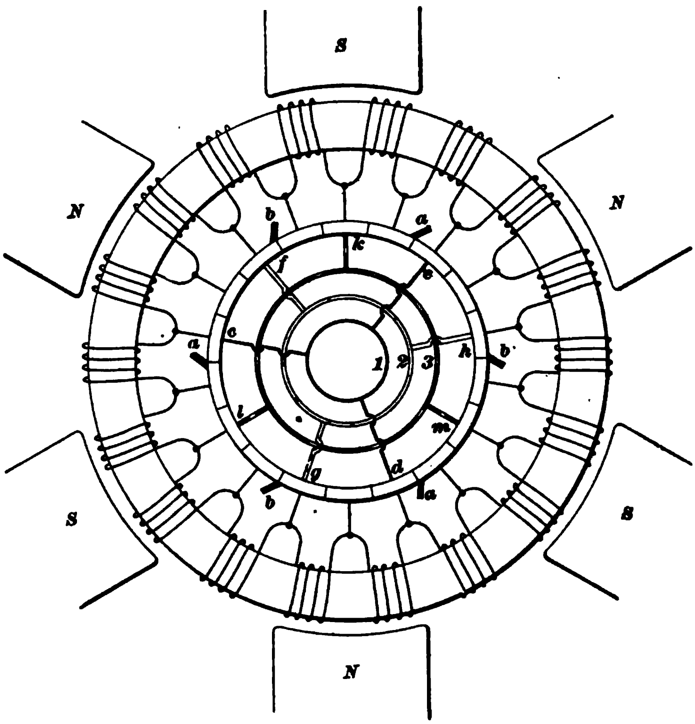


FIG. 3

If the speed of the alternator increases, the speed of the rotaries operated from it will also increase.

The field magnets of a rotary may be either shunt-wound or compound-wound, as in the case of a dynamo, and the current for these windings is supplied from the direct-current side of the machine. Changing the field excitation will not change the speed of the rotary, but it will effect the current that the rotary takes from the line. For each load delivered by a rotary there is a certain field excitation for which the machine takes a minimum current from the line, and the excitation should be kept at this point as nearly as possible. If the excitation is either increased or decreased, the machine will require more current from the line even though the load on the direct-current end may not have increased a particle. If the excitation is increased beyond the point corresponding to the minimum current, the current supplied to the rotary becomes displaced in phase as regards the E. M. F. The current comes to its maximum value during each alternation before the E. M. F., or, in other words, the current is ahead of the E. M. F. Now, when the current and E. M. F. become displaced in this way, there are intervals during each cycle when they are opposed to each other, and the result is that for a given amount of power delivered a greater current is required than if they were always in phase. If the current and E. M. F. were always in phase, they would both alternate together

and the product of the current and E. M. F., i. e., the power, would be always a positive quantity. On the other hand, when they are not in phase, there are times when the current is in, say, the positive direction, while at the same instant, the E. M. F. is in the negative direction. The product of the two at this instant is, therefore, negative, showing that instead of power being delivered it is being returned, with the result that the actual power (watts) delivered to the rotary is less than the product of the current and voltage would indicate. The same is true when the field is under-excited, except that in this case the current does not reach its maximum value until after the E. M. F. or, the current lags behind the E. M. F.

The actual watts supplied are, therefore, equal to the watts apparently supplied multiplied by some quantity which takes this phase difference into account. When the excitation is adjusted so that the current and E. M. F. are exactly in phase, this quantity is 1, because then the actual watts are found by taking the product of the volts and amperes. The quantity by which the apparent watts must be multiplied to give the actual watts is called the *power factor*, or we may write, power factor $= \frac{\text{actual watts}}{\text{apparent watts}}$. The power factor is always less than 1 unless the E. M. F. and current are in phase; for example, the power factor of an alternating-current induction motor may be from .7 to .9, depending upon the size of the motor and the load it is carrying. Since, therefore, the power factor of a rotary depends upon the field excitation, and since the power factor should always be kept as high as possible in order to keep the line current down to a minimum, the field excitation of these machines should be carefully attended to.

Another interesting feature of the rotary converter is the relation that exists between the alternating-current voltage and the direct-current voltage. The direct-current voltage of a three-phase rotary is 1.63 times that supplied to the alternating-current side. For a two-phase rotary it is about 1.414 times the direct-current voltage. The exact ratios vary somewhat with the shape of the alternating E. M. F. wave. If a three-phase rotary delivers direct current at 500 volts, the alternating current must be supplied at a pressure of about $\frac{500}{1.63} = 306$ volts. In order to increase the direct-current voltage, the alternating pressure must be increased. This can be done to a limited extent by increasing the field excitation, but the range of voltage regulation obtained in this way is not large. If a wide variation in voltage is desired, the transformers, supplying the rotary, may be provided with primary coils divided into sections so that, by means of a multi-point switch, the voltage delivered by the transformers can be varied. Another plan is to connect potential regulators in series between the transformer and the rotary.

The current in the armature conductors of these machines is of a very peculiar character. It is the difference between the alternating current supplied and that delivered, because it must be remembered that the machine is acting as a motor at one side and a dynamo at the other. Nearly all the power taken in at one side is delivered at the other, but the current that actually flows in the conductors is not as great as if the machine were made to deliver the same output and run as an ordinary dynamo by means of a

pulley. Or, looking at it another way, a machine for a given direct-current output as a rotary converter does not need to be as large as would be necessary if it were driven as a regular direct-current dynamo. If a three-phase converter had an output of 100 K. W. direct current, when driven by means of a pulley, it would give an output of about 134 K. W. when run as a rotary converter, the amount of armature heating being the same in each case. Rotary converters are, therefore, smaller than direct-current machines of corresponding speed and output.

When a converter is operated inverted, i. e., supplied with direct current, it operates as a direct-current motor, and behaves very much like other direct-current motors. The speed is now no longer fixed, but varies with the field strength and also with the nature of the load on the alternating-current side. An increase of field strength makes the rotary slow down; a decrease speeds it up. Care must be taken never to open the field circuit of an inverted rotary while it is in operation, otherwise the machine may develop such a high speed as to cause serious damage.

The above are a few of the peculiarities of this interesting piece of electrical machinery. Space does not permit here to take up the various methods of starting and operating rotaries. There are so many different methods of starting that a separate article could well be devoted to them.

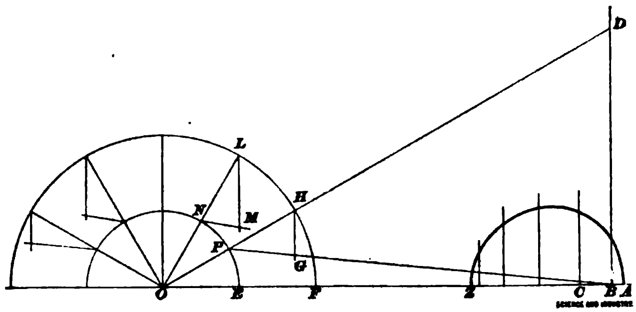
PICTURE TELEGRAPHY

MANY attempts, more or less successful, have been made to transmit pictures through a telegraph line. Elisha Gray and others have used the writing telegraph to make facsimile drawings at a distance, and Sczepanik has devised an apparatus intended to enable us to actually see by telegraph, but this apparatus is complicated, and has not as yet been practically successful. Herr Otto von Bronk has devised a simple and ingenious apparatus for printing at the receiver a photograph of any illuminated object placed in front of a lens at the transmitter. Herr von Bronk makes use of the wonderful susceptibility of steel wires to magnetic strain, utilized by Poulsen in his telegraphone. The image of the object is thrown by a photographic lens on a surface made up of a mosaic of selenium cells. Selenium is a substance whose electrical resistance varies with the intensity of the light that falls upon it. Each cell is in circuit with one of a series of electromagnets arranged so as to produce transverse magnetic strains in a ring of steel wire, each strain being, of course, proportional to the intensity of light acting on its corresponding selenium cell. These strains are reproduced on a similar ring at the receiving station by a synchronous rotating arm. By reversing the original operation, the magnetic copy of the picture is retranslated into an optical one, a photographic negative being produced.—Electrical Review.

PISTON VELOCITY

C. C. WILSON

IN designing an engine, it is not enough to know that the port area is sufficient, so that when the valves are wide open there will be no wire-drawing of the steam, but it is equally essential to know that the valves are opened fast enough to prevent it at any part of the stroke. If we know the piston area, the allowable velocity of steam, and the piston velocity, it is possible to ascertain if the valves are opened fast enough, for the area of the valve divided by the area of the piston should not be less than the velocity of the piston divided by the allowable velocity of the steam. The velocity of the piston for any position of the crank or part of the stroke can be readily determined from a piston-velocity diagram constructed as follows:



Referring to the accompanying figure, let the crank and connecting-rod of the engine be represented by OP and PB. Draw OB, the line of stroke of the engine and the crankpin circle NPE and divide this into 30-degree arcs beginning at E. Find the position of the outer end of the connecting-rod when the crank has turned through the angles of 30 degrees, 60 degrees, etc., and at these points B, C, etc., erect perpendiculars to the line OB. The velocity of the crankpin (assumed to be uniform) is $\pi \times$ stroke of engine $\times RPM$. Let EF represent this velocity in feet per minute, and with O as a center and radius OF draw circle LHF. Prolong the lines representing the crank in its different positions until they cut the circle LHF, and from these points of intersection, H, L, etc., drop perpendiculars to line OB which cut the connecting-rod in the points G, M, etc. Then HG represents the velocity of the piston when the crank has turned 30 degrees from its outer dead point, the scale being that used for the crankpin velocity EF. For, if OP be prolonged and cut the perpendicular through B at D, then D is the instantaneous center for the link PB and the velocities of the ends P and B are directly as the lengths DB and DP, which have the same ratio as HG and HP. Lay off these lengths, HG, LM, etc., on the perpendiculars through B, C, etc., and through the points thus obtained draw a curve starting fron the outer dead point of piston A.

This is the piston-velocity diagram, and the velocity at any point of the stroke is represented by the vertical distance from the point on the line AZ to the curve.

The area of the valve opening for this point of the stroke being determined from the valve mechanism, we can ascertain if it is sufficient.

For the back stroke, the velocities will be given by the same diagram, but it must be noted that the starting position is from the point Z and that the piston is not moving so fast the first part of the stroke.

suitable range; R a resistance of such a value that the battery B will furnish its normal amount of current; and K a simple switch or key. Let B be the internal resistance of the battery, C the current measured by the ammeter A, E the electromotive force of the cell when the external circuit is open at the switch K, and V the difference of potential across the cell terminals when C amperes are flowing through the circuit. Then, $E - V$ is the drop or fall of potential necessary to drive the current C through the battery against the internal resistance B. But this fall of potential by Ohm's law $= B \times C$; hence,

$$B = \frac{E - V}{C}.$$

B is the internal resistance of the

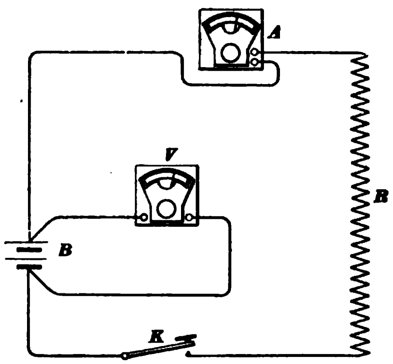


FIG. 1

battery at an output of C amperes. At another rate it may be quite different.

If the total resistance R external to the battery is known the ammeter will not be necessary; for the current C is equal to $\frac{V}{R}$ and can therefore be calculated.

To make the necessary observations, proceed as follows: With the switch K open read the voltmeter. This gives E the electromotive force on open circuit, because the voltmeter is the only circuit through which current can flow. But the resistance of a suitable voltmeter would be very high compared to the internal resistance, and so little current would be taken that it would not appreciably affect the electromotive force of the cell at all. Then, having previously adjusted the external resistance R to give the desired current, close the switch K and read both meters, one after the other, as quickly as possible. The ammeter reading will give the current C, and the voltmeter the difference of potential V at the cell terminals when it is furnishing the current C.

It is best to test single cells, but several connected in series, thus forming a battery, may be tested in this way. In this case the electromotive force and internal resistance of a single cell is found by dividing the results calculated from the observations by the number of cells connected in series to form the battery. The objection to this lies in the fact that one defective cell would probably condemn the whole battery.

For a time test these three readings should be taken at regular intervals, the circuit being opened at K merely long enough to obtain the electromotive-force reading E. One curve plotted with time as abscissas and E as ordinates, and another curve with time as abscissas and B as ordinates, show very nicely how these quantities E and B vary with the time. Similar curves for different cells are excellent guides for comparing the various cells and materially assist in deciding which of several makes or of different types may be the best cells.

USEFUL IDEAS

TAKE-UP DEVICE

For Use in Connection With Detent on Indicator

The great trouble experienced when using the detent on the steam-engine indicator is that of the slack given up by the cord between the paper drum and reducing bushing on wheel. This slack, if not properly guided when throwing on the detent, is liable to get foul, thereby in many instances wrecking the instrument or at least breaking the cord, causing delay and inconvenience to the operator.

The take-up device is used for the purpose of doing away with all this annoyance. It is simple in its construction and can be applied to any standard indicator.

As shown in the accompanying illustration, it consists of a short horizontal arm, at one end of which is a vertical bearing, in which sets a steel pillar, on the upper end of which there is a frame holding a double set of loose steel rollers. Between these the cord from paper drum passes. On the lower end of the vertical pillar there is a light spiral spring enclosed. This spring causes the upper frame to revolve when the cord becomes slack, and is so arranged that the cord winds on the frame, to be given up again when tension is applied.

The object of the device is to permit the operator to take as many cards as desired without unhooking from the crosshead or stopping the engine, no matter what speed. This, of course, pertains to indicators that are fitted with a detent and using a direct-con-

nected reducing motion, the latter being by long odds the most popular in modern engineering practice.

Where an indicator is used in connection with pendulum, lazy tongs, or reducing motion attached to the engine frame, not so much trouble arises, and generally a rubber band is employed to take care of the slack cord, which works fairly well. In this case, the take-up device has been arranged in the shape of a regular guide pulley to connect direct to the indicator. The guide pulley is removed and this put in its place, wound up, and it is ready for use (this can also be used with satisfaction as a guide pulley if not needed to take up slack cord, as the little pulleys are arranged to let the cord run through with perfect freedom), and immediately the detent is engaged, it picks up instantly what slack cord takes place. The tension of the spring in this device being so much weaker than the drum spring, as soon as the detent is disengaged the cord is instantly released and drawn out taut, and assumes its regular position.

The take-up device is not confined to these uses only. It is also attached to engine frames and used in various other ways.

It is strong, well made, and compact, and makes a very attractive attachment. It is good for any number of revolutions and is designed to fit all standard indicators and reducing wheels, or it can be made as a special fixture.

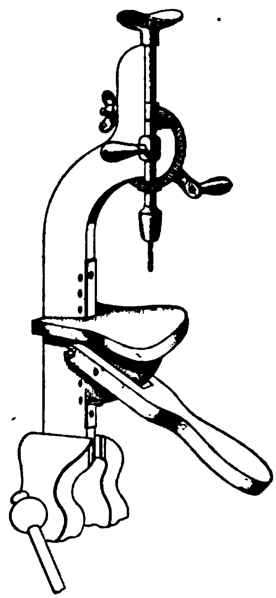
A HOME-MADE DRILL PRESS

Thomas C. Harris

When the amateur mechanic undertakes to drill a number of small holes in metal, using for that purpose a slender twist drill, in an ordinary breast drill stock, he is likely to have trouble. The small-sized twist drills will hardly bear the sidewise strains likely to occur and, being very brittle, they easily snap off.

The accompanying figure shows a home-made drill press, using a common breast drill stock as a part of the machine. For holes up to ¼ inch diameter it does well. For larger size holes the hand power is scarcely sufficient.

The body, or frame, of the press is a



hardwood board, 1 inch thick, sawed out on a jig saw to the shape as shown. The drill stock is held firmly in a vertical groove by the band and bolt, with a wing nut at the rear.

The drill table has a slot cut out to embrace the vertical frame closely and is held thereon by a strap of iron screwed across the opening. Under the table is a bracket of quadrant shape, firmly fastened to it by wood screws. The bracket holds the table at right angles to the frame and has, at its lower end, an iron clip which embraces the edges of the vertical strap of iron which is screwed to the front edge of wooden frame.

This arrangement secures a true up-and-down movement of the table, which is fed to the drill by a forked hand lever. This lever is pivoted to the bracket and engages a pin or wire nail thrust through holes bored for that purpose. An upward movement of the lever raises the table and work against the point of the drill, and a downward movement lowers it. The feed is regulated by the hand on the lever, and is ample for the purpose.

While in use the frame is gripped in the jaws of a bench vise, either in a vertical position, as shown, or it may be held horizontally.

Any pattern of breast drill stock may be so rigged, and will form a useful addition to the amateur's kit of tools.

EDITORIAL COMMENT

Commencing with the January, 1903, number, which will be the first one of the new volume, we shall inaugurate some slight changes in the appearance and general quality of the contents of SCIENCE AND INDUSTRY.

Realizing that the advertisements in a magazine are often of as much interest to readers as the regular contents, the front cover page, instead of the design, "Science Instructing Industry," will hereafter contain an advertisement of some article of interest to engineers.

In the preparation of articles, we shall endeavor to retain the same clear style in presenting practical subjects that has made the magazine popular in the past, and, at the same time, publish such a class of articles as will make the magazine of interest to the engineering profession in general.

With this number we issue the index for Volume VII, this number being the last one of the volume. The index consists of two parts, the General Index and the Alphabetical Index. The General Index includes the titles of all articles and is divided into three parts, viz., Mechanical, Electrical, and Miscellaneous, the articles of each class being grouped together and alphabetically arranged.

The titles of all books reviewed are also included in this index arranged in the class to which they belong.

The Alphabetical Index includes, besides the articles and books, all the Answers to Inquiries, the whole being alphabetically arranged regardless of class.

The supplement for the November number was delayed in printing until too late to be sent out with that issue. We are consequently enclosing it with the December number.

As before stated, this supplement consists of a table giving the allowable carrying capacities of rubber-covered and waterproof wires ranging in size from No. 18 to No. 0000, B. & S. gauge, and of stranded cables up to 2,000,000 circular mils area.

Elsewhere in this issue will be found an article entitled "Elementary Principles of Electromagnets—V". This is a continuation of a series on this subject published in former issues of this volume. The former articles explained the theory of the electromagnet, while this one consists of a practical example illustrating the application of the principles formerly laid down.

The serial articles appearing in the November number will be continued in January.

BOOK REVIEWS, CATALOGUES, AND TRADE NOTES

HANDBOOK ON ENGINEERING. By Henry C. Tulley. Published by Henry C. Tulley & Co., St. Louis, Mo. Third Edition. Price $3.50.

We reprint herewith our mention made of the second edition of this book in the April issue of SCIENCE AND INDUSTRY. The book has since been revised and enlarged, but its general character remains the same.

"This book, as the subtitle indicates, is a practical treatise on the care and management of dynamos, motors, boilers, engines, pumps, inspirators and injectors, refrigerating machinery, hydraulic elevators, electric elevators, air compressors, rope transmission, and all branches of steam engineering. Persons desiring information in regard to the theory of engineering matters, or desiring to make an exhaustive study of some particular branch, can find plenty of books suitable to their purpose; but a handbook is intended for reference and should consequently contain information on questions which are liable to come up in every-day work. This Mr. Tulley's book unquestionably does, and we take pleasure in recommending it to our readers."

HANDBOOK ON LINEAR PERSPECTIVE. By Otto Fuchs. Published by Ginn & Co., New York. Price $1.25.

This book is designed to meet the demand for a comprehensive treatise of perspective drawing for use by students in art schools, colleges, high and normal schools, and by architects, artists, and draftsmen generally. It begins with lucid explanations of the elementary principles; then, by means of carefully selected and graded problems, it develops a series so comprehensive that the entire ground is covered, from the first rudiments to the requirements of the architect's office and the artist's studio. Every problem is at once instructive and interesting, and free from all dry and wearisome theory. The work is not at all voluminous and yet is complete.

The plates are printed on separate sheets so that they may be placed side by side with the text, in order to keep the explanations and the drawings constantly connected.

The volume is a small quarto consisting of 44 pages and 13 plates.

We are in receipt of a copy of a new catalogue recently issued by the Union Steam Specialty Co., 131 Franklin Avenue, Scranton, Pa., which is complete in every respect. The catalogue is devoted particularly to indicators, reducing wheels and planimeters, and gives, in a condensed form, complete specifications of the instruments, and section views and engravings of the instruments in use, so that any one looking over the catalogue hastily may get from the "pictures" the main points which the manufacturers desire to bring out. Special circulars are included of the "Scranton" steam pump, the "Lippincott" steam separator, shaking grate bars, furnace blowers, and other steam specialties.

The advantage of metallic packing as a steam stopper has been demonstrated to such an extent during the last few years that there is scarcely an engine built today for which there is not some form of metallic packing specified. The ever-increasing demand has led many firms to experiment in its manufacture, with the natural outcome that numerous infringements and law suits have resulted, ending with one or the other firm going out of business, until today there are only a few brands recognized as genuine. Among these, and perhaps the most prominent, is that manufactured by A. W. France, Tacony, Philadelphia, Pa., whose business has increased to such an extent that Mr. France has recently formed a company with a capital of $100,000 to be known as the France Packing Co., Inc.

The attention of our readers is called to the announcement of the Stephenson Mfg. Co., on page 31 of this issue. In a personal letter to the Editor, Mr. E. A. Kellogg the treasurer of the company, of Albany, N. Y., writes us that upon request he will give any reader of this paper an order on his nearest and best mill-supply dealer for a pound stick of Stephenson Bar Belt Dressing absolutely free of cost.

W. H. Wakeman, author and publisher of "Engineering Practice and Theory," has issued a circular of testimonials from readers of his book. There are thirty-six of them, and they prove that the book is appreciated by engineers all over the country.

On another page we print a description of a new take-up device for use with the indicator. Full information in regard to it can be obtained from the manufacturers, James L. Robertson & Sons, New York.

ANSWERS TO INQUIRIES

NOTICE

Address all letters containing questions to be answered in this department to Editor "Science and Industry," Scranton, Pa.

Put each question on a separate sheet of paper.

The drawings or sketches for each question should be made on a separate sheet of paper and should be as clear as possible, care being taken that they correspond correctly to the question as stated.

Owing to the large number of questions received we can only answer those which are of general interest to our readers.

On account of the time required for making drawings, cuts, printing, etc., we cannot always answer questions in the issue immediately following their receipt. Questions are answered in the order in which they are received and as soon after their receipt as possible.

We cannot answer questions by mail except in case of urgent necessity.

The name and address of the writer must accompany each question as an evidence of good faith, or no attention will be paid to it. Unless otherwise requested, we will publish only the initials and address of the writer.

We cannot undertake to calculate the windings of dynamos and motors, as this involves the expenditure of more time and work than is justified.

Inquiries previously answered should be referred to by number and volume.

MECHANICAL

(309) After having received the blasting signal and started to hoist men from a mine, one of the eccentrics on a twin-hoisting engine slips. There are no valves between the main throttle valve and either engine. What course would you pursue, knowing that three-minute fuses are being used?

B. F. B., Bonner, Mont.

ANS.—In such an emergency as this we would advise that the throttle be closed and the pin connecting the eccentric rod and valve stem be driven out and the valve moved to the middle point of its travel. Both ports will then be covered and steam will thus be kept out of the cylinder so that the cage can be hoisted by means of the other engine.

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(310) (*a*) Which would give better service, two engines of 5 and 7 horsepower, respectively, coupled to one shaft, or one engine of 12 horsepower? (*b*) Would the 7-horsepower engine use some of its power to run the smaller?

G. M., San Francisco, Cal.

ANS.—The 12-horsepower engine would be the more economical. The mechanical efficiency or ratio of the delivered horsepower to the indicated horsepower decreases very rapidly as the size of the engine decreases. The loss from friction, cylinder condensation, etc., in a 5-horsepower and a 7-horsepower engine would considerably exceed the corresponding loss in a 12-horsepower engine. (*b*) No. Each engine would deliver to the shaft its excess over the power required to overcome its own frictional resistances, and since each engine is transmitting power to the shaft, there could be no transmittal of power from the shaft to either engine.

***

(311) (*a*) Which is the more economical in the use of steam, a simple or compound engine, when working at one-fourth the rated capacity? (*b*) Why?

F. E., Woosung, Ill.

ANS.—(*a*) Generally speaking, the compound engine is more economical. (*b*) The reason for this is the reduction in the amount of cylinder condensation through the use of two cylinders. It is well to bear in mind that compounding practically doubles the friction of an engine, and if the power to be delivered is small, the gain by the use of two cylinders may be more than counterbalanced by the increased friction. It will be seen from this that the size of the engine enters into the problem. An engine of small power would be uneconomical as a compound, because the friction would constitute such a large per cent. of the total power, and an engine of large power would be uneconomical as a simple engine, because of the excessive cylinder condensation. It is also seen that there is a point at which an engine would be economical as a compound if worked to its full capacity, and yet uneconomical when worked at only one-fourth its full power.

***

(312) In constructing a railroad track the joints are always laid opposite each other and on the same tie. You will find, when standing between the rails of a track that has been used for some time and facing either end of the track, that the joint on the right hand side is leading the one on the left. In other words, the rails are traveling in opposite directions. Can you give a reason for this?

M. D., John Day, Ore.

ANS.—The joints of the rails in a railroad track are not always laid opposite each other and on the same tie, though this is a common practice. We are unable to see any reason for the two rails traveling in opposite directions under the traffic, and do not think they do so. It is probable that the movement of both rails of a track under the traffic is substantially the same on a

straight line, though it may not be the same on curves. If in a straight track the right-hand rail joints are in advance of a position directly opposite the left-hand joints, it is probably because they happened to be laid so. In a double track, however, where the traffic on each track is constantly in the same direction, it is sometimes found that both rails of each track tend to advance, or "creep" in the direction of the traffic. This is especially the case on bridges and trestles.

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(313) (*a*) In a link-reversing steam engine, as a locomotive, should the radius of the link be the distance from the center of the crank-shaft to the center of the link, when the link is in mid-position and the valve in the center of the travel? (*b*) Should the link hanger be vertical when the link is in mid-position and the valve in mid-position also, or should it be vertical when the link is raised or lowered in order to give the full throw of the eccentric?

J. I. G., East Providence, R. I.

Ans.—(*a*) Opinion differs considerably as to what length of link radius helps to produce the best motion of the valve. Some consider the radius of the link to be the distance between the centers of the link-block pin (lower rocker-arm pin) and the eccentric when the valve motion is in full gear, in which position the link-block pin is directly opposite the end of the eccentric rod. Others take the distance between the center of the axle and the center of the lower rocker-arm pin. A committee appointed by the American Master Mechanics' Association to decide on this question for the Association, recommended that the distance between the center of the axle and the center of the lower rocker-arm pin be adopted as the proper radius of the link. At the same time, they advised that the link motion be so planned as to give the longest link radius possible under the circumstances and yet use the length of link radius recommended. (*b*) The valve motion is so designed that the link hanger stands vertical when the valve motion is in mid-gear and the valve in mid-position.

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(314) We have a boiler that supplies 12 radiators with steam and there are no valves on the return pipes to the main line. We are running the water back to the bottom of the boiler. When we shut off the steam the system begins to knock and hammer. The pressure in the steam boiler is 20 pounds. What is the trouble?

J. D. H., Milmont, Wash.

Ans.—There are many different defects in heating plants that produce water hammer, and it is very difficult for us to tell you precisely which one is the cause of your trouble, for you have not given us enough information to base proper conclusions upon. If there are no valves on the return pipes from the radiators it is rational to assume that when the steam valve to any radiator is closed, the boiler water will back up the return pipe and flood that radiator. This will show a considerable and quick fall of your boiler water-line, and hammering may, or may not, result according to the tightness of the steam valve. A good swing check-valve placed on the return main will hold the water steady in the boiler, but in order to prevent condensation water in other return pipes from backing into the radiators, it is advisable to place a valve on each radiator return pipe. In plain words, place a valve on each end of each radiator if the job is piped on the two-pipe system. If this does not remedy the evil, send us a sketch and description of the job and we will be pleased to give you a more definite reply in another issue of Science and Industry.

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(315) (*a*) Which is the best and most economical valve next to the Corliss? (*b*) Which is the most difficult valve to set? (*c*) How would I proceed to set a Meyer cut-off valve? T. W. W., Sudbury, Can.

Ans.—(*a*) Opinions differ. The requirements of a good valve gear are that it open the valve quickly and widely, does not wire-draw the steam because of a slow cut-off, and does not absorb much power in friction. It is conceded that the Corliss valve gear fulfills these to a greater extent than any other, but hardly any two engineers would agree on the next best valve. (*b*) Valves requiring indirect measurements are, perhaps, the most difficult for a beginner. (*c*) To set the slide valve with the Meyer cut-off, it is first necessary to put the engine on center. This is done by turning the engine until the crankpin is 3 or 4 inches from its center position. Now scribe a mark on the rim of the flywheel by means of a tram resting on some convenient fixed point about the engine. On the crosshead and guide scribe a line so that the crosshead can be brought back to exactly the same position. Next turn the engine so that the crankpin is on the opposite side of the center and the mark on the crosshead and guide again come in line. Make another mark on the flywheel rim with the tram. Divide the distance between the marks on the flywheel equally and by turning the engine bring the middle point under the tram point. The engine is now exactly on center. Turn the main-valve eccentric on the shaft until the valve shows the proper amount of lead, and temporarily secure it at this point. Turn the engine to its other center, and if the lead is the same as before, the main valve is set. If it is not, move the valve on its stem until the leads are equal, and then move the eccentric on the shaft until the desired lead is obtained. To set the cut-off

valve, turn the screwed valve stem until the cut-off plates are as far apart as they are designed to go. Turn the engine until the piston has traveled to the earliest point at which cut-off is designed to take place, and then move the cut-off eccentric on the shaft until it just closes the port at that end. Turn the engine over and if cut-off occurs at the same point on each stroke, the valve is set. If it does not, equalize the point of cut-off by changing the length of the valve stem, and then turn the eccentric shaft until cut-off takes place at the required point again. Secure both eccentrics.

***

(316) Please give me a method of calculating the required pitch of the teeth of a gear, when the greatest strain on the teeth is known, and the width of the face is fixed. For instance, I have a load of 16,000 pounds coming on the teeth of a gear 20 inches in diameter and 4-inch face, the gear being of cast iron. This load is the greatest that can come on the gear, and comes while the gear is at rest. W. H. L., Boston, Mass.

ANS.—The conditions which you have fixed are such that it is impossible to obtain any practical solution to the problem. Take the formula,

$$C = \frac{16.8\,p}{S\,b},$$

in which C = circular pitch; p = load on the tooth in pounds; $S = 4{,}200$ for cast iron; and $b = 4$ in. = face of the gear. According to this,

$$C = \frac{16.8 \times 16{,}000}{4{,}200 \times 4} = 16 \text{ in.}$$

The thickness of the tooth at the pitch line being equal to about half the circular pitch, it would have to be 8 inches thick. Such a tooth thickness for a gear 20 inches in diameter is, of course, utterly absurd. It will be impossible for you to obtain a gear of the stated diameter and face, to withstand the given load. It will be necessary for you to change some of the conditions. For slowly moving cast gears the face should be from 2 to 3 times the circular pitch, and we see no better way than for you to alter the dimensions of your gear.

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(317) Please tell me how to find the middle ordinate on a chord of 15′ 5″ with a 10° curve.

W H. P. Columbus, Ga.

ANS.—The middle ordinate m to a chord of any length in a circular curve of any radius can be computed by the formula:

$$m = R\sqrt{R^2 - \frac{c^2}{4}},$$

in which R is the radius of the curve and c is the length of the chord; all values being expressed in the same unit. In the example given it will be best to reduce values to feet. The length of the chord is 15′ 5″ = 185 inches $= \frac{185}{12}$ feet. The radius of a 10° curve is 573.69 feet. By substituting these values in the above formula, we find the middle ordinate required is equal to .052 foot = ⅝ inch, closely.

***

(318) I wish to heat a house of eight rooms with steam or hot water from the boilers of electric-light station 1.200 feet away, with the minimum outlay for pipe. Steam pressure will vary between 50 pounds during the day to 100 pounds at night. Will an ejector in cellar heat the water for a two-pipe system of hot-water heating? The ejector to be supplied with live steam from the boilers through a ¾-inch pipe, 1,200 feet long. I have been told that ¾-inch pipe is not large enough, but I think if it should require all the steam a ¾-inch pipe will carry at 100 pounds pressure to heat the house it would be very expensive heating.

A. B., Pitman Grove, N. J.

ANS.—You have not stated the size of the building to be heated nor the approximate amount of heat that will be lost through walls, windows, etc., and by changing the air in the building. We will, therefore, assume that the building is about 30 feet square, 20 feet high, with about 300 square feet of glass surface. Under ordinary conditions, during zero weather, the heat loss will be about as follows:

Through walls and ceiling	= 30,000 B. T. U. per hr.
Through windows	= 20,000 B. T. U. per hr.
Change of air twice per hour	= 50,000 B. T. U. per hr.
Approximate total heat loss per hour	= 100,000 B. T. U.

$$\text{The weight of steam required} = \frac{100{,}000 \text{ B. T. U.}}{1{,}000 \text{ B. T. U.}} = 100 \text{ lb. per hour.}$$

The size of pipe required to deliver this weight of steam per hour from a boiler carrying 50 pounds pressure and discharging against a back pressure of 25 pounds is theoretically about ¾ inch in diameter Allowing for corrosion, ejector resistance, and other obstructions that are liable to affect the flow, we would not advise the use of a smaller pipe than 1 inch, and it must be well covered. We fear the injector will make too much noise for comfort in the house, otherwise we believe the heating will be satisfactory. It is customary in such a case to heat the building with steam-heated radiators, placing a pressure-reducing valve on the live steam main inside the cellar, the water of condensation from the radiators being discharged to the sewer through a steam trap and a cooling coil. The trap prevents steam escaping from the system, yet allows the water to escape. The cooling coil cools the water of condensation before it escapes to the sewer and thus prevents damage to these pipes. If a hot-water heating system is employed in the house, and heated by steam,

it is customary to place a live steam coil inside a closed tank or heater and circulate the water so heated, between the heater and the radiators. If you use an ejector you must have an overflow to the hot-water beating system.

ELECTRICAL

(319) (*a*) In the case of a two-phase alternator, provided with three slip rings, and connected to a two-phase, three-wire circuit, are the currents in the two phases in opposition part of the time? (*b*) A storage battery consists of two sets of cells in multiple. The E. M. F. of the battery is 60 volts. The safe load on the battery is 12 K. W. Two motors in series are connected across the terminals of the battery. What will be the E. M. F. across the terminals of each of the motors and how will the load be divided between them? (*c*) Is it the practice to connect both ends of a trolley feed-wire to the same side of a generator, instead of connecting only one end, when the trolley line makes a complete loop. Would not this lessen the resistance of the complete circuit? (*d*) How does a compound-wound dynamo maintain a constant E. M. F. at its terminals at all loads? (*e*) What is meant by consequent poles as used in connection with street-car motors? (*f*) Is alternating current used in telephone or telegraph work and at what pressure and frequency? E. H. O., Philadelphia, Pa.

Ans.—(*a*) Yes. The current in the middle wire is not represented by twice the current in one of the external wires, but is equal to $\sqrt{2}\, I$, where I is the current in one of the outside lines. (*b*) Thirty volts. Each motor will take one-half of the total load if the motors are similar and running under like conditions. Each motor will take 6 K. W. to run it. (*c*) In order to be able to cut out a section of trolley, from the station, the feeders may be run from the station both ways around the loop. In this case there would be two or more separate feeders. If it is not desired to cut the loop into sections, the feeders may be connected as suggested. This would virtually make two feeders in multiple, instead of having only one feeder, as would be the case if the feeder were connected at one end only. There would be less resistance from a car to the station, along the feeder, if the feeder were connected at both ends, than if connected at only one end. (*d*) The total current flowing through the external circuit flows through the series field coil. As the line current increases the current in the series coil increases, which increases the magnetic flux through the machine and causes a higher E. M. F. to be generated in the conductors on the armature. This higher E. M. F. makes up for the loss in volts in the armature windings and tends to keep the E. M. F. at the terminals of the dynamo the same at all loads. In many compound-wound dynamos the series coil is so proportioned that the E. M. F. at the terminal of the dynamo rises as the load comes on, thus making up for drop in volts in the line, so that the E. M. F. at some point out on the line may remain nearly constant at all loads. (*e*) The consequent poles are set up by the opposing magnetic action of two neighboring field coils. The field coils set up lines in the frame of the motor that oppose each other in direction. These lines are deflected down through the consequent pole pieces and armature and form complete magnetic circuits. (*f*) In telegraph work direct current is usually used. Lines using alternating current have been devised. In telephone work alternating currents and direct currents are used. No definite frequency or pressure of alternating current is ordinarily used, as for instance in the case of a magneto; the frequency and E. M. F. depend upon the speed at which the magneto handle is turned.

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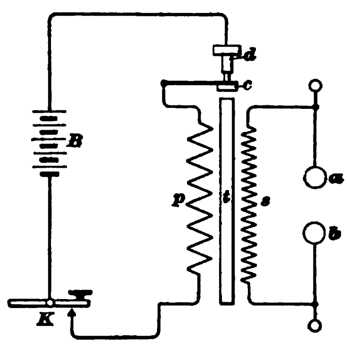
(320) Please give me a description and diagram of the wireless telegraph transmitter. C. O. R., Ontario.

Ans.—A simple diagram, stripped of all details, however, of a wireless telegraph transmitter is shown in the accompanying figure. It consists of an induction coil capable of giving at least a 6-inch spark, a battery *B* and a key *K* by means of which the Morse telegraph signals



are made. It is usually customary to set the knobs *a b* not over one inch apart, to connect one of them to the ground and the other to a long vertical wire. Marconi sometimes uses a wire extending 150 feet into the air. There should also be a condenser connected across the spark gap between *c* and *d*. You will find two articles on wireless telegraphy in the "Steam Electric Magazine" for February and March,

1899. In a book, entitled "Wireless Telegraphy" by R. Kerr, you will find directions for making wireless telegraph apparatus. You can buy this book from Technical Supply Co., of Scranton, Pa., and you can get the magazines mentioned for ten cents apiece by addressing SCIENCE AND INDUSTRY, Scranton, Pa. On page 612 in the December, 1901, SCIENCE AND INDUSTRY, is given the dimensions and material required for a 6-inch spark coil.

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(321) Will alternating current, after having been passed through a transformer, charge a storage battery?

A. W. M., Washington, D. C.

ANS.—It is necessary to have a direct current in order to charge a storage battery. An ordinary transformer delivers an alternating current, and hence the current delivered from the secondary could not be used to charge storage batteries. If the alternating current were passed through a rotary transformer and changed to direct, it could be used for charging.

***

(322) Is there any rule for changing amperes to watts or horsepower, without knowing the volts or resistance?

H. D. F., Brooklyn, N. Y.

ANS.—No. The watt is a unit of power, whereas the ampere is the unit of current. The power depends upon the product of the current C and the E. M. F. E; hence, watts $= C \times E = C^2 R$.

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(323) In the sketch sent herewith, a $\frac{1}{6}$-horsepower motor is belted to a $\frac{1}{6}$-horsepower dynamo and batteries are attached to the motor as shown. The object of the battery is to start the motor, after which the battery is switched off and the current from the dynamo then runs the motor. The motor takes a current of 1 ampere at 6 volts and the dynamo will give 6 amperes at 50 volts. (a) Can I use part of the current from the dynamo to run the motor and the rest to run lamps? (b) How much resistance should I use in a rheostat for regulating the speed of the motor?

A. W., Davisburg, Mich.

ANS.—(a) and (b) We have not reproduced the sketch referred to above, because the whole scheme of operation is impossible on the face of it. The sketch shows a small motor belted to a dynamo. A motor of 6 watts capacity would not drive a dynamo of 6 watts output, to say nothing of one having an output of 300 watts. If this were possible the problem of perpetual motion would be solved, and there would be 294 watts left over. You cannot create power simply by running current through two machines. If your motor delivered $\frac{1}{6}$ horsepower you would not get $\frac{1}{6}$ horsepower from the dynamo, because of the losses in the two machines. To keep the motor going it would therefore be necessary to supply current from some outside source in addition to that supplied from the dynamo, so that you cannot obtain current for lighting lamps from any such combination of machines as is shown in your sketch.

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(324) (a) Will a hollow permanent magnet be as strongly magnetized throughout the center as it will on the outside? For example, if a steel pipe were magnetized, would the magnetic lines inside the pipe be as strong and as many as along the outside of the magnet? Would it behave like a solenoid? (b) If so, would the hollow magnet draw up a piece of soft iron within itself like a coil of wire through which a current was passing? (c) Could a drill be magnetized strongly, without first drawing its temper by using a current of 6 amperes? (d) How shall I treat cast steel or good tool steel to make permanent magnets? Shall I harden the ends? G. M., Beloit, Wis.

ANS.—(a) and (b) No; there will be very little magnetism in the center, because the iron or steel is a so much better conductor of magnetism than the air within the tube that very few lines of force pass through the center. There will therefore be little or no magnetic force within the tube. (c) Yes; it is not necessary that the temper be drawn. If the temper is drawn, the drill will not retain its magnetism; if it is left hardened, it will retain considerable magnetism after the magnetizing coil has been removed. (d) Heat it to a cherry-red heat throughout and plunge into water. This will make the steel very hard and it can then be magnetized by winding a coil around it and sending a heavy current through the coil. The bar should be hardened throughout, not at the ends only.

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(325) Will you please tell me what is wrong when the current from a dry battery connected to an induction coil becomes suddenly weaker or suddenly stronger at times, when the coil and battery are moved around? The coil is on the same base as the battery. C. A. A., La Grange, Ohio.

ANS.—There is probably a loose connection somewhere that makes an irregular connection whenever the coil is moved. It may also be due to the fact that the contact maker works better in some positions than in others.

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(326) Please tell me what is the best form of a grease trap for a sink, and where I can get it. E. C. D., Cherryfield, Me.

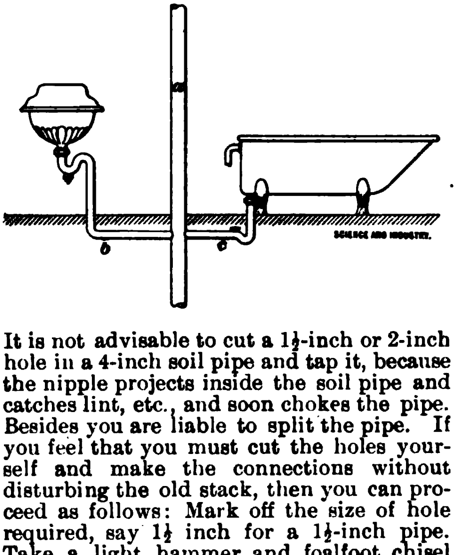
ANS.—One of the best form of a grease trap is of the water-jacket form, known as the Tucker grease trap. It is sold by The Meyer Sniffen Co., 5 East Nineteenth Street, New York.

MISCELLANEOUS

(327) (*a*) I have a 4-inch cast-iron soil pipe *a* and desire to tap it and put in a 1½-inch or 2-inch wrought-iron pipe for waste connections *b* and *c* (see accompanying figure) for the bath and basin. How can I cut the holes and make the connections? (*b*) Should the vent pipe of the lavatory enter the soil pipe below or above the floor? The soil pipe goes up through the roof. (*c*) How are the connections made to a hot-water boiler of the standard galvanized iron type, having a capacity of 30 gallons, and located in the kitchen? I want to connect it to the water front in the stove, and to the bathtub and lavatory, and the kitchen sink.

C. H. P., Oshkosh, Wis.

ANS.—(*a*) The best plan of procedure is to engage a plumber to cut the soil pipe and insert a 4″ × 2″ Y on the soil stack, then run the bath and basin branches into the 2 inch Y; or a 4″ × 2″ double Y may be used.



It is not advisable to cut a 1½-inch or 2-inch hole in a 4-inch soil pipe and tap it, because the nipple projects inside the soil pipe and catches lint, etc., and soon chokes the pipe. Besides you are liable to split the pipe. If you feel that you must cut the holes yourself and make the connections without disturbing the old stack, then you can proceed as follows: Mark off the size of hole required, say 1½ inch for a 1½-inch pipe. Take a light hammer and foalfoot chisel and cut a groove into the cast iron just inside the circle. Then cut through the pipe about the center of the hole and chip outward, making the hole larger by chipping till the circle is reached. Then trim off the edges to receive a 1½-inch tap (standard gas-pipe thread). Now tap the hole, easily, till it fits the nipple. Then screw in the nipple with red lead. Care must be taken, however, to prevent the nipple projecting inside the stack. If any fixtures discharge into the stack above this new connection, you must insert a Y branch or look for future trouble in the way of chokage. Your sketch shows the nipples *b* and *c* in line with each other. This is a mistake, for each pipe will discharge into the other; besides, it necessitates two holes in the stack. It would be better to connect *b* and *c* with a Y fitting. You should also back-vent the bath and basin traps. We advise you to engage a plumber to do this work, because the danger from sewer gas in your home is too great to warrant you in experimenting on the soil pipes. (*b*) In Home Study for the Building Trades, August, 1897, page 28, you will find a long article containing valuable information on this subject. (*c*) In Home Study, February, 1896, page 1, appears an article on "Hot-Water Supply and Boiler Connections." This will show how such work is done. You can obtain these back numbers by enclosing 10 cents for each, and mailing your order to The Editor of SCIENCE AND INDUSTRY, Scranton, Pa.

***

(328) (*a*) What is the best method of preserving a wooden pile from teredos or other worms, and how should the remedy be applied? (*b*) What will be the cost for the process on a pile 18 inches in diameter? (*c*) How can I best preserve piling that has been driven several years?

E. M. C., Tampa, Fla.

ANS.—(*a*) We presume that the piling to which you refer is principally subjected to the attack of sea worms between mean ebb and mean low tide. There are several methods by which the ravages of these worms may be retarded. Probably the best method, under the circumstances, would be to cover the piles with copper sheathing. We, however, assume that the cost would be excessive. A temporary method is to paint the piles with a carbolic paint. A paint of this character will protect the piles as long as the qualities of the paint remain intact, and the period of protection might extend over several years. The most efficient method for the cost, that we know of, consists in first painting the piles with a carbolic paint, then with an asphaltum paint, wrapping around the coating of asphaltum, spirally, canvas or bagging saturated with asphaltum paint, and finally coating the entire covering again with asphaltum. There are many patented processes for treating timber piles in order to protect them against sea worms and decay. They are, however, expensive, and of doubtful utility. We would mention also that there is an English silica paint made which has temporary properties for protecting piles from the ravages of teredos. (*b*) It is impossible for us to quote you the price of the several preservative methods which we have mentioned. We do not know for what the

materials can be purchased in your locality, nor do we know the price of labor. You should be able to figure the cost far more closely than we. (*c*) The only method by which you can preserve the piles in place, and which have been driven for several years, would be to cover them, as we previously suggested, with copper. The expense of this being too great, coating them with a carbolic paint at low tide would be the next best expedient; but it is very doubtful whether any preservative method can be successfully employed where the piles have been driven for some time. Undoubtedly, the damage created by the worms in several years would be irretrievable.

***

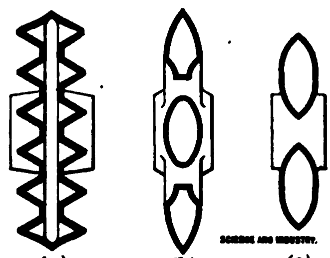
(329) (*a*) If three radiators of the same height and having the same amount of surface are built up of the sections shown at *a*, *b*, and *c* in accompanying figure, what will be their relative values when used as direct radiators with hot water? (*b*) What are the relative values of two radiators having the same amount of surface, one being 38 inches high and the other 25 inches? (*c*) In hot-water heating, what is a safe ratio between the heating and radiating surface, for a well-designed sectional cast-iron boiler? For a wrought-iron water-tube boiler? (*d*) What should be the cost per foot of radiation of a good hot-water system in dwellings requiring from 350 to 800 square feet direct radiation? (*e*) Is there any method of polishing a marble slab that has been rubbed with emery paper?

G. B. M., Nankin, Ohio.

ANS.—(*a*) According to the results of numerous tests made of the heating efficiency of such radiators, we would expect that the two-column radiator would emit about 1.75, the three-column radiator about 1.7, and the flue radiator about 1.4 B. T. U. per hour per square foot per degree difference between the air in the room and the radiator surface. (*b*) The 38-inch radiator should emit about 1.75 B. T. U. and the 25-inch radiator about 2 B. T. U. per hour per square foot per degree difference. (*c*) The proportions vary with the capacity of the boiler, etc. For a boiler capable of supplying 1,000 square feet direct hot-water radiation, the following proportions show a fair average:

Heating surface in boiler	118 square feet.
Grate area	4.5 square feet.
Diameter of smoke pipe	12 inches.

The proportion between heating surface and grate surface is usually a little larger in wrought-iron tube boilers and varies with the construction. (*d*) This depends on the market prices. You can get quotations from the manufacturers, or a contractor's price for the job. (*e*) First rub the piece by means of another piece of marble, or hard stone, with the intervention of water and two sorts of sand; first with the finest river or drift sand, and then with common house or white sand, which latter leaves the surface sufficiently smooth for the process of gritting. Three sorts of grit stone are employed: first, Newcastle grit; second, a fine grit brought from the neighborhood of



(*a*) (*b*) (*c*)

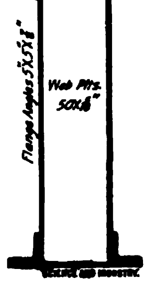
Leeds; and lastly, a still finer, called snake grit, procured at Ayr, in Scotland. These are rubbed successively on the surface with water alone; by these means, the surface is gradually reduced to closeness of texture, fitting it for the process of glazing, which is performed by means of a wooden block having a thick piece of woolen stuff wound tightly around it; the interstices of the fibers of this are filled with prepared putty powder (peroxide of tin), and moistened with water; this being laid on the marble and loaded, it is drawn up and down the marble by means of a handle, being occasionally wetted, until the desired gloss is produced.

***

(330) Kindly explain the method of finding the weight that may be supported at the center of a plate girder having the section shown in the figure. The span of the girder is 60 feet.

B. S. McC., Philadelphia.

ANS.—It is assumed that the plate girder in question is properly proportioned for shear and the buckling of the web-plates. The resisting moment of a plate girder is determined by the formula $M_1 = a\,s\,D$, in which a equals the area in square inches of the upper or lower flange, and in calculating this area it is customary to consider the net areas of the flange plates, flange angles, and ⅛ of the depth of the web-plates; s equals the allowable unit fiber stress, which for structural steel is taken at from 15,000



to 18,000 pounds; D equals the depth of the girder in feet, and while the theoretical depth is the distance between the centers of gravity of each of the flange sections, it is usual to assume the depth of the girder as

being equal to the width of the web-plate. The bending moment on a beam supported at both ends and carrying a concentrated load at the center is expressed by the formula $M = \frac{WL}{4}$, in which W is the weight and L the length of the girder in feet. For any girder to supply sufficient strength to support the imposed load, M must equal M_1, or $\frac{WL}{4} = asD$; then $WL = 4asD$, and $W = 4\frac{asD}{L}$. In the problem which you propose, the gross flange area of the girder is as follows:

Area flange plate	$= 22 \times .625$	$= 13.75$ sq. in.
Area 2 flange angles	$= 4.23 \times 2$	$= 8.46$ sq. in.
Area ⅛ web plates	$= .25 \times 8.33 \times 2 =$	4.16 sq. in.
Total area		$= 26.37$ sq. in.

The net area of the flange is equal to the gross area, from which has been deducted the metal in a single section cut out for rivet holes. Assume that in this instance the area to be deducted for rivet holes equals 4.5 square inches; then, the net flange area will equal $26.37 - 4.5 = 21.87$. The depth of this girder can be taken, especially if there is more than one flange plate, as equal to the width of the web-plate, or 4.16 feet; the span of the girder is 60 feet, and a safe unit fiber stress of 15,000 pounds is assumed. These values may be substituted in the formula for obtaining W, and

$W = 4\frac{21.87 \times 15{,}000 \times 4.16}{60}$, or 90,976 lb.,

which is the load that the girder will safely support when the weight is concentrated at the center.

***

(331) Construct in a circle a rectangle, such that the product of one side by the square of the other side is a maximum.
F. H. C., New York, N. Y.

ANS.—Let a = radius of circle;
$2y$ = one side of rectangle;
$2x$ = other side of rectangle.

Then, from the figure,

$$x^2 + y^2 = a^2.$$

Whence, $\quad y = \sqrt{a^2 - x^2}.$

Then, by the conditions of the problem, $(2x)(2y)^2$ is to be a maximum.

Since $y = \sqrt{a^2 - x^2}$; $(2x)(2y)^2 = 8a^2x - 8x^3$.

Let
$$u = 8a^2x - 8x^3; \qquad (1)$$
$$\frac{du}{dx} = 8a^2 - 24x^2; \qquad (2)$$
$$\frac{d^2u}{dx} = -48x. \qquad (3)$$

Letting $\quad \frac{du}{dx} = 0,\ 8a^2 - 24x^2 = 0;$

solving, $\quad x = \frac{a}{\sqrt{3}}.$

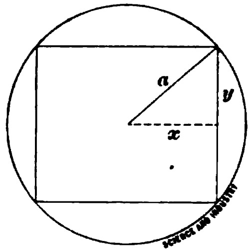
Substituting $\frac{a}{\sqrt{3}}$ for x in (3),

$$\frac{d^2u}{dx} = -\frac{48a}{\sqrt{3}};$$

which shows that $x = \frac{a}{\sqrt{3}}$ is a maximum.

Then, since

$$y = \sqrt{a^2 - x^2},\ y = \sqrt{a^2 - \frac{a^2}{3}} = a\sqrt{\frac{2}{3}}.$$



Hence, when one side of the rectangle is $\frac{2}{\sqrt{3}}a$, and the other is $2a\sqrt{\frac{2}{3}}$, the product of the side $\frac{2a}{\sqrt{3}}$ into the square of the side $2a\sqrt{\frac{2}{3}}$ will be a maximum.

***

(332) A and B dig a ditch 100 feet long, for which they receive \$50.00 each. B receives 25 cents per foot more than A for the amount he digs. How much does each dig and what is the price per foot that each receives? G. M., San Francisco, Cal.

ANS.—

Let $\quad x$ = number of feet A digs;
y = number of cents per foot A receives.
Then $y + 25$ = number of cents per foot B receives.
$100 - x$ = number of feet B digs.

From the conditions of problem,

$$xy = 5{,}000 \qquad (1)$$
$$(100 - x)(y + 25) = 5{,}000 \qquad (2)$$
$$\text{or, } 100y - xy + 2{,}500 - 25x = 5{,}000 \qquad (3)$$

From (1), $\quad x = \frac{5{,}000}{y} \qquad (4)$

Substituting (4) in (3),

$$y - 75 - \frac{1{,}250}{y} = 0$$

Or, $\quad y^2 - 75y - 1{,}250 = 0$

Then, $\quad y = \frac{75 \pm \sqrt{75 + 5{,}000}}{2}$

$y = 89.038+$

Substituting in (4) $\quad x = 56.155$

Whence,

$100 - x = 43.845;\ y + 25 = 114.04$

Hence, A digs 56.155 feet and receives \$0.8904 per foot; B digs 43.845 feet and receives \$1.1404 per foot.

Table of Allowable Carrying Capacities of Wires

B. & S. Gauge	Rubber-Covered Wires. Amperes	Weatherproof Wires. Amperes	Circular Mills
18	3	5	1,624
16	6	8	2,583
14	12	16	4,107
12	17	23	6,530
10	24	32	10,380
8	33	46	16,510
6	46	65	26,250
5	54	77	33,100
4	65	92	41,740
3	76	110	52,630
2	90	131	66,370
1	107	156	83,690
0	127	185	105,500
00	150	220	133,100
000	177	262	167,800
0000	210	312	211,600

Allowable Carrying Capacities of Stranded Cables

Circular Mills	Rubber-Covered Amperes	Weatherproof Amperes
200,000	200	300
300,000	270	400
400,000	330	500
500,000	390	590
600,000	450	680
700,000	500	760
800,000	550	840
900,000	600	920
1,000,000	650	1,000
1,100,000	690	1,080
1,200,000	730	1,150
1,300,000	770	1,220
1,400,000	810	1,290
1,500,000	850	1,360
1,600,000	890	1,430
1,700,000	930	1,490
1,800,000	970	1,550
1,900,000	1,010	1,610
2,000,000	1,050	1,670

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Vol. VII DECEMBER, 1902 No. 12

SCRANTON, PA., U. S. A.

Entered at the Post Office at Scranton, Pa., as Second-Class Matter

SCIENCE AND INDUSTRY

VOL. VII - - - - - - No. 12

PUBLISHED MONTHLY BY

INTERNATIONAL TEXTBOOK COMPANY, Proprietors

SCRANTON, PA., U. S. A.

IRVING McC. BEAN - - EDITOR

Special Contributors

R. B WILLIAMSON, M. E

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Communications relating to the Editorial Department of SCIENCE AND INDUSTRY, including questions for answer in the "Answers to Inquiries" Department, should be addressed "Editor of SCIENCE AND INDUSTRY, Scranton, Pa."

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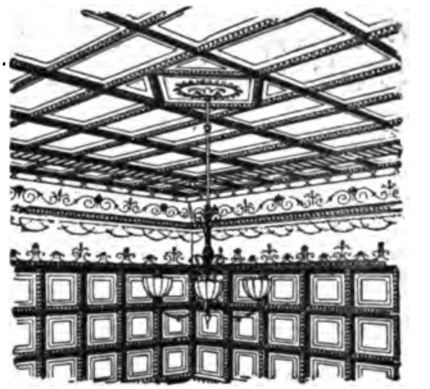

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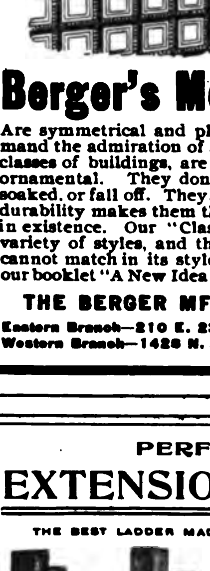

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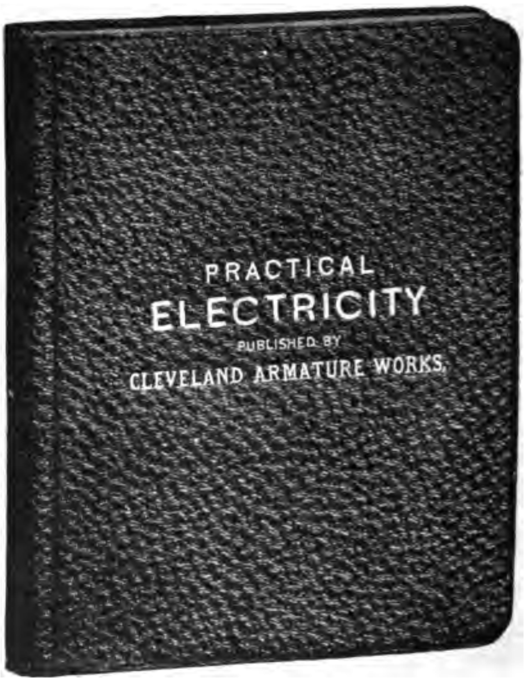

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